

**The synthesis of a unified pedagogy for the design and  
evaluation of e-learning software for high-school computing.**

**Vol 2 of 3 - Appendices**

**by**

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Appendices document submitted in partial fulfilment for the requirements for the degree of  
Doctor of Philosophy at the University of Central Lancashire

June / 2019

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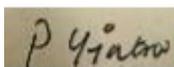
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# **A TEACHER AND EXPERT FEEDBACK ON THE E- LEARNING PEDAGOGY**

A crucial factor in the development and validation of the e-learning pedagogy was its evaluation and the corresponding input of multiple teachers and education experts which spanned across all three research phases. In the interest of brevity, Chapter Six of the thesis presents abridged findings from the teacher and education expert evaluations; specifically, these findings are presented in section 6.4, in Tables 25, 26, 27 and 28.

This appendix elaborates the findings from Phase 1, 2 and 3 with a richer description and supporting quotes from evaluators.

## A.1 Phase 1 - Teacher and Expert Feedback on the E-learning Pedagogy

As discussed in sections 3.4.2.2 and 6.4.1 of the thesis, the review of the Phase 1 e-learning pedagogy by five education experts and one teacher provided the feedback outlined in this section; this feedback was based on the pedagogy document GCSE Computer Science E-Learning Pedagogy v0 7.

Education Expert 3 and Teacher 1 gave direct feedback that the heuristics are appropriate for 15/16-year olds, appropriate for teaching computer science and feasible for usage in schools. The other respondents did not give direct feedback on these points. It should be noted that the teacher did comment that some heuristics may be difficult to implement in a classroom setting, the following heuristics were mentioned as being more appropriate for students using the software and Collaborative Learning Environment (CLE) from home.

- CV1 – The development and nurturing of networks is a major component of learning.
- CV2 - The network can be cultivated to form a community.
- CV3 - Information is constantly changing, therefore, its accuracy and validity may change over time.

Additionally, Education Expert 1 expressed the concern that the framework for GCSE study does not lend itself to *“collaboration”*. The term collaboration refers to collaborative learning between students and typically facilitated and supported by their teacher.

Education Expert 2 and Teacher 1 expressed some concern over heuristic CL1.1 Static illustrations can be better than animations. The concern being that static illustrations are only more appropriate sometimes and that in general *“Students can understand better when they see the actual movement instead of having to go over several static illustrations.”* [Teacher1]

Overall, none of the reviewers expressed disagreement with any of the heuristics or that there were any significant gaps in the heuristic coverage. In fact, two of the experts expressed the opinion that:

*“Comprehensive, detailed and well- organised overall, well done!”* [Education Expert 3]

*“...it is a very thorough document”* [Education Expert 4]

Education Expert 5 expressed the following recommendations:

*“I did wonder about the need for engagement with the content and was thinking about gamification and rewards and maybe about variation and even, dare I say it, fun.”*

*“I also wonder about how the different principles pan out in different 'elements' of the CS curriculum....”*

Education Experts 2 and 3 provided detailed feedback within the pedagogy document that commented on grammar, spelling, phrasing, clarity of expression and moderating strong wording; these were

discussed with the expert reviewers and where appropriate have been incorporated into the Phase2-Cycle1 version of the pedagogy document.

Upon the suggestion of Education Expert 2, heuristic titles were updated and rephrased to a uniform structure and language aimed at improving clarity. Additionally, based on feedback, the sequence of heuristics was adjusted, and some heuristics were grouped as sub-heuristics.

Education Experts 2, 3 and 5 requested a greater focus on describing how heuristics may contradict each other.

Education Experts 2 and 3 made comments about using terminology that may not be well known to the target audience hence the decision to include a glossary.

Education Experts 4 and 5 commented on the non-standard approach to referencing. After discussion, these comments were agreed to be a misunderstanding since the light approach to referencing was specifically used to assist the readability of the pedagogy document. It was clarified that standard academic referencing would be used in the thesis literature review.

Education Expert 2 commented that in computer science cooperation and collaboration are used with a difference in meaning, and therefore this should be expressly discussed in the pedagogy and clarified as to whether the pedagogy uses the terms interchangeably.

Based on feedback and follow up discussion with Education Experts 2 and 3, and considering that the objective of the pedagogy is the design and/or evaluation of e-learning software, not the pedagogical instruction of teachers, it was decided to replace the Educational Change and Technology Implementation sections in favour of a Design and Evaluation section. The objective of the Design and Evaluation section is to provide criteria by which teachers and/or instructional designers can design or evaluate e-learning software.

Additionally, it was noted that not all heuristics neatly fall into a Learning Theory; therefore, a field for Pedagogical Area was added for each heuristic.

Education Experts 2 and 3 commented that the text in the Technology Implementation section of COL2 offers quite an extreme position that may be more of a personal opinion. It was agreed to rephrase and tone down this statement.

*“However, their small form factor inhibits true active engagement and makes them more appropriate for passive information consumption.” [E-Learning Pedagogy v0.7, p45]*

Education Expert 1 did not provide feedback on the heuristics themselves but gave feedback on a more philosophical level directed to the introductory chapters of the pedagogy (Chapters Four and Five). This expert’s feedback focused on:

1. Setting the correct context and audience for the pedagogy; this, in turn, led to adjustments to the pedagogy relating to:
  - a. What is the function of the pedagogical heuristics within the broader project?

- b. What does it draw from?
  - c. What will it feed into?
  - d. What is its purpose?
  - e. How will it be produced? and
  - f. What are the relationships between the heuristics?
2. Concentrating on academic discussion and avoiding the political rhetoric in the UK that disparages ICT in favour of computer science.
  3. Differentiating between what is argued, that which is theorised and that which has supporting evidence and based on this moderating extreme wording and statements.
  4. Several comments were made that were already considered in the research design, but not explicitly discussed in the pedagogy document:
    - a. Focusing the pedagogy on specific content and curriculum as outlined by the Department for Education (DfE).
    - b. Focusing the pedagogy on a realistic school context that compels schools to prepare students to pass exams.

*“The school and the classroom is a very "irrational" and alien place...but it is the environment we are designing for.”* [Education Expert 1]

- c. Defining the rationale for the selection of learning theories included in the pedagogy.

## **A.2 Phase2-Cycle1 - Teacher and Expert Feedback on the E-learning Pedagogy**

As discussed in sections 3.5.3.1 and 6.4.2 of the thesis, the review of the Phase2-Cycle1 e-learning pedagogy by four education experts and one teacher provided the feedback outlined in this section; this feedback was based on the pedagogy document GCSE Computer Science E-Learning Pedagogy v1.2.

### **A.2.1 Document Length and Number of Heuristics**

The restructuring of the previous pedagogy document, the inclusion of additional information on existing heuristics and the inclusion of new heuristics in the areas of motivation, computational thinking and gamification led to a significant increase in the length of the v1.2 pedagogy document; it had grown to 130 pages and 160 pages including references and appendices. This created an immediate challenge in securing evaluation feedback from teachers; as an intermediate step, a v1.3 pedagogy document was created. The v1.3 document is an abridged version of the v1.2 document and was shortened to 106 pages excluding references; the editing process included the following:

1. Introductory sections were either removed or drastically shortened.
2. The glossary was increased, to describe introductory terminology.
3. The reference list at the end of each heuristic was removed.

4. Appendices were moved to a separate document.

The v1.3 document was evaluated by the new teacher (Teacher 2), who joined Phase2-Cycle1.

The length and usability of the document for the intended teacher audience was a common theme amongst the education experts and was reported either in their feedback documents or in the follow-up interviews.

*“...the current document, although being comprehensive and useful may have difficulties in being used by actual teachers and school departments due to its length.”* [Education Expert 3]

Verbally during the evaluation follow-up interview, Education Expert 5 did a basic quantification that there is a very large number of criteria for teachers to consider. In the v1.2 and v1.3 pedagogy, there were 47 heuristics and sub-heuristics, and 231 Evaluation and Design criteria. Furthermore, this does not consider that many of the criteria also have several sub-points. This gives a strong indicator that the number of heuristics and evaluation and design criteria need to be rationalised as much as possible in Phase2-Cycle2.

## **A.2.2 Appropriateness of the Heuristics for 15 to 18 Year Olds (Key Stage 4 & 5)**

Four from the five participants responded that they either agree (three participants) or strongly agree (one participant) that the heuristics are appropriate for 15/16-year olds (Key Stage 4) and 17 / 18-year olds (Key Stage 5). Education Expert 5 did not respond to this question.

Overall, it was reported that the identified heuristics were appropriate for the target age group. Additionally, that any potential challenges in implementing the heuristics were described and could also be considered when implementing the heuristics for specific age groups. It was though noted that the heuristics are not directly correlated according to their suitability to key stages 4 or 5. This is in keeping with the philosophy of the pedagogy; it is a toolset of which specific tools (heuristics) are selected as appropriate based on teacher or designer judgement. This judgement considers many factors, one of which is the specific age group (Key Stage) and maturity of the students. Nonetheless, further analysis of the Department for Education’s (DfE) curriculum for computer science was planned to evaluate whether the heuristics are more appropriate to either of the key stages.

The teacher response to this question offered a more practical insight, he did not comment on the appropriateness of the heuristics to the age group, but instead on the potential challenges in implementing the e-learning software for school students. In particular, the concern was:

*“Students today are bombarded with sources of information, but actually having the ability to distinguish what is most helpful and to actually be able to choose what tool or resource to use may be a challenge by itself.”* [Teacher 2]

The concerns raised by Teacher 2 are relevant and discussed in heuristic 12, which proposes a moderate connectivist approach in which the e-learning software acts as a focal point that recommends other

learning resources to the students. Heuristic 12 also discusses in the Potential Challenges section that the teacher should now reduce their role of presenting learning material and readdress this focus towards teaching students critical thinking and metacognitive skills for them to see connections between fields, ideas and concepts and critically evaluate the learning material that they find.

Integrating the e-learning into existing teaching strategies and schedule, thereby not increasing the overall workload of the students, is reported as an important factor; some suggestions include using the software from home as either homework or as part of flipped teaching, using the software for students who have been absent or as a final revision aid. The key factor is that the software and the underlying pedagogical heuristics must be closely integrated into existing teaching methods and cannot be or perceived to be an additional burden. Teacher 2 commented that *“Being different, engaging and visual could potentially help the likelihood of it being more attractive.”* It should be noted that these criteria are central tenants of the pedagogical heuristics. Engagement and motivation are given focus in heuristics 1, 7, 13, 14 and its sub-heuristics; visual learning is given focus in 16.1 17, and 17.1.

### **A.2.3 Appropriateness of Heuristics for Computer Science Education**

Four from five participants responded regards the appropriateness of the heuristics for computer science education; Education Expert 4 neither agreed nor disagreed, but clarified that *“I am not an expert in CS. However, I believe that many of the items of the heuristic...if not all, can somehow be applied to CS education.”* Two respondents agreed, and the last respondent strongly agreed that the heuristics were appropriate for computer science education.

*“The heuristics are very much appropriate for computer science education as they guide teachers towards achieving goals relevant to this as a distinct subject domain and particular ways in which knowledge can be structured and organised in this domain.”* [Education Expert 3]

*“The heuristics are appropriate for Computer Science education (as well as other STEM subjects). Many of the heuristics, especially the ones related to problem solving are important for fields such as computer science where students are expected to develop skills in problem identification, analysis, solution design etc. as well as evaluation skills drawing on supportive evidence.”* [Education Expert 2]

*“Having in mind my previous answer I would like to add that incorporating heuristics in Computer science or more specifically any STEM type of subject could greatly benefit students, subjects that require or rely on problem solving or an experience, and also being able to actually view something happening can motivate and increase likelihood of a more memorable lesson.”* [Teacher 2]

Education Expert 2 also commented that the heuristics also focus on other skills important to computer science, *“such as working under guidance, working as part of a team and as an individual”*. In addition, that some studies have shown that the multimodal approach proposed in the pedagogy can be more effective in computer science.

Following a similar theme to previous responses, Teacher 2 took a practical perspective and advised that *“Students tend to want a hands-on experience with anything we do the value being able to see something*

*and it makes it memorable for them,”* this is in keeping with the practice-based, kinaesthetic, visual and visualisation heuristics in the pedagogy. However, Teacher 2 warned that *“when something new is provided to them if it’s repeated enough students do start becoming resistant towards it, so the way this is used and how often this is used is something that I consider more important to the appropriateness and the adoption method of the heuristics for computer science in education.”* This supports the overall direction that the pedagogy is a toolset in which the heuristics are tools by which to employ variety, and not a checklist in which each heuristic must be used and must be used as much as possible; balance and variety in usage are more important.

Again, Teacher 2 recognised the benefits but warned *“I believe that if teachers or a school can convey students and staff to use forms of E-Learning software students can only benefit, similar to the use of certain Microsoft software we use in the XXXXXXXX School, teachers can get instant feedback and an understanding of the progress of the students, but again it all comes down to the people actually accepting this into their routine as well.”*

#### **A.2.4 Feasibility of Heuristics to be Implemented in a High School Environment**

Four from five participants responded regards the feasibility of the heuristics in being implemented in a high school environment; Two education experts agreed that the heuristics were feasible to be implemented in a high school environment, one expert neither agreed nor disagreed and importantly the teacher neither agreed nor disagreed.

Education Expert 4 advised that the feasibility of the heuristics within a high school environment depends on how they are used. Whereas, Education Expert 2 advised that the majority of the heuristics can be easily implemented in a high school environment, but some of the heuristics are a bit more challenging to implement in a high school. However, these challenges are documented and addressed in the pedagogy.

Teacher 2 gave a balanced response reflecting that *“any addition to the syllabus can be both good and bad”*. However, that incorporating such heuristics into high schools *“can certainly influence students learning and teaching in a positive manner”*. The challenge is that despite the potential benefits the transition may not necessarily be smooth and would need to be governed by sociocultural factors that require effective change management, which in turn goes beyond whether the heuristics themselves are appropriate for high schools.

#### **A.2.5 Is There Balanced Pedagogical Coverage?**

Four from five participants responded on whether there is a balanced pedagogical coverage in the heuristics, of which three education experts agreed, and the teacher strongly agreed that there is a balanced pedagogical coverage, meaning there are no gaps, weak areas or areas with too much focus.

Furthermore, three participants responded that they have no additional heuristics to suggest and one participant responded that he was not sure.

*“There is a balanced pedagogical coverage with appropriate emphasis on overarching educational theories and key concepts. These are well linked to strategies that guide teaching practice in computer science.”* [Education Expert 3]

*“Reading through the report provided, I find myself inadvertently using a number of the heuristics. All of the heuristics seem to cover every single aspect of a teaching method. Personally, I feel that the best method of teaching is a combination of using real examples, or props, or multimedia and also giving the students the ability to engage in a group discussion.”* [Teacher 2]

Additionally, there were a number of constructive comments:

1. The connection between technology-enhanced learning environments, multimodality and learning have not been clearly made.
2. In places, the heuristics go beyond pedagogy and focus on the affordances of technology and how they can be leveraged to achieve learning outcomes
3. Two education experts acknowledged the importance of computational thinking within computer science but queried exactly how computational thinking should fit in within the pedagogy.
4. There were constructive comments from three education experts on how certain heuristics could be sequenced differently, how some heuristics could be sub-heuristics and the validity of heuristics that are built entirely from other defined heuristics.

## **A.2.6 Structure and Readability**

The overall feedback from the education experts and teacher was positive regards the structure and readability of the pedagogy document.

*“This version of the pedagogy document is much better than the previous version, with good reading flow and structured organisation. The way each pedagogy is presented (the structure of each section) is beneficial to a novice reader, since they can get familiar with the concepts through the Description, look at the Design Evaluation Criteria and also be informed of the Educational Benefits and Potential Challenges.”* [Education Expert 2]

As previously noted, there was a consensus that the document length needs to be shortened which will undoubtedly affect the structure and readability of the next version of the document.

The importance of the heuristic titles was reasserted by Education Expert 2; these need to be intuitively understandable to the teacher audience. It is also under consideration to add a small description for each heuristic in the summary table to give an initial clarity to the audience without having to read the full heuristic description. Additionally, the page number will be included in the summary table to support easy document navigation.

Education Experts 2 and 4 recommended that a categorisation (grouping) of the heuristics would give an additional value to teachers; some suggestions for potential categories were proposed and were considered for further development in the Phase2-Cycle2 pedagogy document.

Education Expert 2 commented that the phrasing in the pedagogy needs to be reviewed since on occasion it is not clear whether guidance or criteria relate to the teacher, the e-learning software or the Collaborative Learning Environment (CLE). As a rule, this pedagogy should focus on the e-learning software and CLE and should not provide pedagogical guidance on teaching practices. It is commented that in some heuristics, information is presented on the learning methodology, but there is no direct reference to the e-learning software, and how the learning methodology relates to it; this needs to be more clearly explained.

Similar to some of the feedback received in Phase 1, one education expert commented on the approach to referencing. This was again discussed and agreed that the literature review in the thesis would be academically referenced but the pedagogy document would not be referenced in the same stringent manner. However, it was argued that the current approach of listing references at the end of each heuristic section does not add value; it was suggested that an even lighter approach listing references in the footnotes could be considered.

## **A.2.7 General Comments**

As previously mentioned, Education Expert 5 did not base her feedback on the evaluation template, in some cases the feedback was not applicable within the context of the pedagogy document, but some of her feedback offered a positive disruptive influence and added important insight.

During the follow-up interview, this education expert advised that the document is very comprehensive and thorough; the quality of the work is not in question, but it is too much information for teachers to use and needs to be reduced and tailored to the teacher audience. The overriding objective is how best this pedagogy could give value to teachers and instructional designers.

*"I think you need a smaller set of heuristics if they are any use for teachers. One way to think is why would I choose x over y... - how are these evaluated with you heuristic set? Which one would 'win?'"* [Education Expert 5]

This also reaffirmed the existing plan that in Phase2-Cycle2 the accompanying evaluation protocol used to evaluate e-learning software according to the heuristics would be updated and released.

Although overall, the section structure for each heuristic received positive feedback, this education expert gave stricter comments that comparatively the content in each section needed to be uniform and balanced between the heuristics. Additionally, that often the text in the description section, although useful, was not always a description.

This expert commented that *"The Related heuristics is messy - how do they relate? if they relate so well why do we have so many - what about heuristics in conflict?"* this, in turn, prompted an increased focus

on conflicting heuristics in the Related Heuristics section and reasserted the need to reduce the heuristics and associated design and evaluation criteria. Importantly, it also triggered a more visual representation of how the heuristics interrelate, using a Red, Amber, Green (RAG) matrix that shows how heuristics support or conflict with each other.

This expert also queried whether each heuristic is useful for every type of e-learning and where each heuristic becomes important? This discussion was similar in nature to previous discussions with the other education experts on grouping the heuristics but culminated in a decision to add another RAG matrix that visually represented the intended benefits of each heuristic.

## **A.3 Phase2-Cycle2 - Teacher and Expert Feedback on E-Learning Pedagogy**

As discussed in sections 3.5.3.3 and 6.4.3 of the thesis, the review of the Phase2-Cycle2 e-learning Pedagogy from three education experts and one teacher provided the feedback outlined in this section; this feedback was based on the pedagogy document GCSE Computer Science E-Learning Pedagogy v1.5.

### **A.3.1 Appropriateness of heuristics for 15 to 18 years olds (Key Stages 4 & 5)**

All four participants responded that they either agree (one participant) or strongly agree (three participants) that the heuristics are appropriate for 14-16-year olds (Key Stage 4) and 17 / 18-year olds (Key Stage 5). Overall, it was reported that the identified heuristics are appropriate for the target age group. Additionally, that any potential challenges in implementing the heuristics are described, and can also be considered when implementing the heuristics for specific age groups.

The heuristics are not directly correlated according to their suitability to Key Stages 4 or 5. This is in keeping with the philosophy of the pedagogy; it is a toolset of which specific tools (heuristics) are selected as appropriate based on teacher or designer judgement. At the suggestion of Education Expert 3, further analysis of the Department for Education's (DfE) curriculum for computing was carried out and showed a strong alignment between the heuristics and learning objectives for both Key Stage 4 and 5. With reference to Figure 1, the pedagogical heuristics defined in Phase2-Cycle2 provide support for Key Stage 4 Learning Objective 1 and strong support for Learning Objective 2.

## Key stage 4

All pupils must have the opportunity to study aspects of information technology and computer science at sufficient depth to allow them to progress to higher levels of study or to a professional career.

All pupils should be taught to:

- develop their capability, creativity and knowledge in computer science, digital media and information technology
- develop and apply their analytic, problem-solving, design, and computational thinking skills
- understand how changes in technology affect safety, including new ways to protect their online privacy and identity, and how to identify and report a range of concerns.

Figure 1: Key Stage 4 Learning Objectives for Computing.(DfE 2014b, p.230)

With reference to Figure 2, the pedagogical heuristics defined in Phase2-Cycle2 provide strong support for Key Stage 5 Learning Objectives 1 through 4.

3. AS and A level specifications in computer science must encourage students to develop:
  - an understanding of, and the ability to apply, the fundamental principles and concepts of computer science, including abstraction, decomposition, logic, algorithms and data representation
  - the ability to analyse problems in computational terms through practical experience of solving such problems, including writing programs to do so
  - the capacity for thinking creatively, innovatively, analytically, logically and critically
  - the capacity to see relationships between different aspects of computer science
  - mathematical skills (as set out in the attached annex)
  - the ability to articulate the individual (moral), social (ethical), legal and cultural opportunities and risks of digital technology

Figure 2: Keys Stage 5 (A-Level) Learning Objectives for Computer Science (DfE 2014a, p.1)

The Teacher 3 response to this question offered strong agreement that the heuristics are appropriate for the target age group, and the teacher comments gave insight into how specific heuristics offer support:

*“In my opinion Problem based learning provides more opportunities for exploring and not focusing on just a fixed answer. Make expert and learner thinking processes explicit is the key for KS5 student esp. in relation to accommodate new learning. I feel with higher order thinking is developed more by Engage learners in a challenge; target learning towards the zone of proximal development (ZPD).”* [Teacher3]

### **A.3.2 Appropriateness of heuristics for Computer Science Education**

All four participants responded that they either agree (one participant) or strongly agree (three participants) that the heuristics are appropriate for computer science education.

*“Learning theories which have been developed based on computer science education have been integrated in the broader discussion on theories and relevant heuristics originating from these theories have been implemented. Generally, all heuristics point to computer science education.”* [Education Expert 3]

The teacher response to this question offered strong agreement that the heuristics are appropriate for computer science, and the teacher comment gave insight into how specific heuristics offer support:

*“I strongly agree Computer Science education focuses more on Problem based learning and prompt reflective practice to support learning. It is very important to build foundation on Computational thinking before using it.”* [Teacher 3]

### **A.3.3 Feasibility of Heuristics to be Implemented in a High School Environment**

The three education experts agreed that the heuristics were feasible to be implemented in a high school environment, but the teacher neither agreed nor disagreed.

As discussed previously, the pedagogy is designed as a toolkit in which heuristics that can be selected based on the specific learning material, intended audience and intended learning outcomes. In this respect, the majority of the heuristics can be implemented in a high school environment without difficulty. However, some of the heuristics have a bit more challenge to be implemented in a high school; these challenges are also documented and addressed in the pedagogy.

Although the overall findings seem modestly positive, this remains an area of concern because although the heuristics are feasible to be implemented in high-schools, they may not necessarily align with the reality in some UK schools. This sentiment is echoed by one education expert and the teacher:

*“The heuristics do not take into consideration of the broader school curriculum, ethos, timetable and goals because this is not part of this study. Overall, the heuristics as they stand could be implemented in a high school setting.”* [Education Expert 3]

*“I could evidence that many of the heuristics are already implemented in high school environment. All schools focus on results-oriented learning so even though they implement many of the suggested heuristics. I think new learning happens only when students carry out projects on their own or practical activities.*

*...there is very little time provided for student- content which deepens learning and this is one of the key area being ignored when considering why progression of students taking computer science from KS4 to KS5 is not 100%.”* [Teacher3]

The conclusion is that when designing e-learning software or evaluating software for the basis of selection, the heuristics that will be applied must also consider the reality of the school context in which the software will be used.

### **A.3.4 Is there balanced pedagogical coverage?**

All four participants responded on whether there is a balanced pedagogical coverage in the heuristics, of which Education Experts 2 and 3, and Teacher 3 strongly agreed, and Education Expert 4 agreed that there is a balanced pedagogical coverage. Teacher 3 went further to applaud the inclusion of heuristics on computational thinking and gamification.

Furthermore, three participants responded that they have no additional heuristics to suggest and the teacher offered one suggestion that students should be taught to embrace mistakes as opportunities to learn.

*“Computer Science is a subject whereas a student/teacher/programmer I enjoyed correcting mistakes and never gave up. This is covered in pedagogy document briefly but in my opinion I start my every year of teaching by saying you must make mistakes and correct it by yourself. Mistakes – find why it happens and how to correct it – deeper learning.”* [Teacher3]

This point is not covered in a discrete heuristic, but is covered explicitly in heuristic 14.3 guideline-3 and 15.1 guideline-3; it is also touched upon in heuristics 7 and 7.1.

### **A.3.5 Structure and Readability**

In Phase2-Cycle 1 the length and usability of the document for the intended teacher audience was a common theme amongst the Education Experts and was reported either in their feedback documents or in the follow-up interviews.

*“...the current document, although being comprehensive and useful may have difficulties in being used by actual teachers and school departments due to its length”* [Education Expert 3].

The feedback in Phase2-Cycle1 led to the following changes in the pedagogical heuristics document:

1. The number of heuristics and evaluation and design criteria were rationalised as much as possible in order to shorten the document,
2. The re-sequencing of heuristics,
3. The heuristic titles were re-evaluated, and many changed to ensure greater clarity,
4. A small description and page number was provided for each heuristic in the summary table,
5. The phrasing in the pedagogy was re-evaluated to ensure greater consistency,
6. The removal of the reference listing at the end of each heuristic,
7. The movement of introduction and non-essential text to a separate appendix document,
8. The inclusion of a glossary to mitigate the removal of introductory text,
9. The re-evaluation of content in each section to ensure greater consistency and balance between the heuristics,

10. More depth in the Related Heuristics section and the addition of a Red, Amber, Green (RAG) matrix that shows the interrelationship between heuristics,

11. The addition of a Red, Amber, Green (RAG) matrix that shows the intended benefits of each heuristic.

The aforementioned changes led to significantly shortened, restructured and updated pedagogy document for Phase2-Cycle2. These changes were well received by the respondents, who commented that:

*"This version of the pedagogy document is much better than the previous version, with good reading flow and structured organisation. The way each pedagogy is presented (the structure of each section) is beneficial to a novice reader, since they can get familiar with the concepts through the Description, look at the Design Evaluation Criteria and also be informed of the Educational Benefits and Potential Challenges."* [Education Expert2]

*"Extremely clear and very well structured. As I have mentioned earlier very detailed description and I have already started to evaluate my teaching. Clear references to the different heuristic technique made it easier for me to look at the different approaches."* [Teacher3]

In addition, all four participants responded that they either agree (one participant) or strongly agree (three participants) that the educational benefits of each heuristic are clearly described. The respondents commented that:

*"Educational benefits for each heuristic are well described and discussed. The discussion can provide the necessary motivation to the reader to follow/apply the presented heuristic. Also, examples are provided in some cases which can help the reader better understand the benefits."* [Education Expert 2]

*"I could clearly see education benefits of each heuristic approach has been clearly explained."* [Teacher3]

*"They are clearly described with some good examples. Care was taken not to follow a restrictive and reductionist approach that may hinder creativity."* [Education Expert 3]

The written and verbal feedback from Education Experts 2 and 3 confirmed the value of the Educational Benefits Matrix but commented that the context of use and limitations of the matrix need to be communicated to the audience before presenting it.

All four participants responded that they agree the interrelationships between heuristics are clearly described. Although the respondent feedback is encouraging, it seems there remains some room for improvement. The respondents commented that:

*"The Heuristics Interrelation Matrix is very helpful for the high level understanding of the relation between heuristics, although the matrix is not accompanied by any explanation/description. The information provided in the "Related Heuristics" section for each heuristic helps create the connections between the heuristics and better understand the provided matrix."* [Education Expert 2]

*"Overall this is well described with space for improvement, please see comments in text."* [Education Expert 3]

In the follow-up interview with Education Experts 2 and 3, it became clear that the size and intricacy of the interrelationship matrix is a challenge for legibility when viewed on a smaller screen (laptop screen). Furthermore, the matrix represents the interrelationships between the heuristics as reflected in the significant but ultimately constrained literature review; this, in turn, reflects some relationships which may seem counterintuitive to some education experts. Therefore, the context of use and limitations of the matrix need to be communicated to the audience before presenting it. In addition, it was discussed whether a higher-level mind map might, in fact, provide a more natural visual representation. This is an area to be investigated in Phase 3.

Education Experts 2 and 3 also provided minor comments in the pedagogy document; typically related to spelling, grammar and phrasing.

Education Expert 2 suggested that a further categorization of the heuristics (e.g. authentic learning, problem-based learning/practise activities, collaborative learning, motivation, multimodal learning, etc.) could add value.

There was also a comment that for novice readers the inclusion of more internal links between heuristics, appendices and glossary could add value in providing the reader with additional information or clarifications.

It is understandable that the appendices document has not undergone the same number of iterations and therefore has more room for improvement. This was commented by one education expert:

*“There is huge improvement in relation to the previous draft. In addition to what is being mentioned above, I have reservations over inconsistencies in the uses of referencing material in the appendices and some other issues noted in text.”* [Education Expert 3]

Since the value and suitability to teachers of the pedagogy have to some extent been questioned, it was very gratifying that an experienced teacher gave such positive comments of the pedagogy:

*“Truly exceptional research and since I am currently exploring more about computational thinking I personally found this as a very useful addition to my other books and documents on this subject.”* [Teacher 3]

However, despite the reduction in length and improvements in structure, consistency and readability of the document, there remained some concern on whether it was truly usable for the intended teacher audience.

*“This is certainly a valuable and rich resource for teachers, however the complexity and length might prevent some to fully utilise and put into practice. E.g. a school would need a series of staff meetings to discuss this document and many mentoring sessions will be required for teams of professionals to use. Similarly, for designers this is a useful resource, yet it requires time and effort to be understood.”* [Education Expert 3]

## A.4 Phase 3 Workshop - Supplementary Teacher Feedback on the E-Learning Pedagogy

As discussed in sections 3.7.3 (more specifically, sections 3.7.3.2.1 and 3.7.3.2.2) and 6.4.5 of the thesis, the Phase 3 study for the E-learning Evaluation Protocol was encompassed within a teacher workshop in which a substantial portion of the workshop was dedicated to educating the teachers on the e-learning pedagogical heuristics. However, at this point, these teachers did **not** have access to the e-learning pedagogy document and the opportunity to evaluate it in detail. For this reason, the strength of the following findings should not be overstated; they offer only supporting evidence of the appropriateness and validity of the e-learning heuristics.

When asked to comment on the appropriateness of the heuristics for 15 to 18 years olds (Key Stages 4 & 5), both focus groups offered consensus that they are appropriate:

*“They seem to be very appropriate. They give a good grounding for evaluating (and designing) learning resources in general, even though the focus was E-Learning.”* [Evaluator 1]

Similarly, when asked to comment on the appropriateness of the heuristics for computer science education, both focus groups offered consensus that they are appropriate:

*“Very appropriate. The availability of a computer lab tends to tempt teachers to take on unwise additions to teaching, just because the facilities make it possible. Being able to evaluate the benefits of learning resources ensures that they are not added just because the computer lab makes it possible, but because they're useful instead.”* [Evaluator 1]

*“They were certainly appropriate for the computer science.”* [Evaluator 13]

Overall, both groups offered a consensus that the heuristics offered balanced pedagogical coverage:

*“I think there is balanced pedagogical coverage.”* [Evaluator 3]

*“I don't believe there's a gap. My general impression is that they are thorough and balanced.”* [Evaluator 1]

Furthermore, neither group suggested any new heuristics or pedagogical areas not already considered:

*“As stated above, there were no areas that were lacking or missing. If anything, the heuristics broadened my understanding of good pedagogy.”* [Evaluator 1]

*“There's nothing new, I have in mind.”* [Evaluator 2]

There was one exception in the evaluator responses regards balanced pedagogical coverage and the potential for new heuristics. Evaluator 13 commented that *“at the moment there is no balance. There are many gaps and weak areas”*. Furthermore, that new heuristics could be introduced that cater to *“complex problems that involve cognitive aspects and principles”*. These responses were collected via the survey instrument alternative to the Group 1 focus group. Unfortunately, a follow-up request to clarify and

elaborate on these comments did not receive a response. In the absence of further comment from the evaluator and in consideration that these responses are out of step with the other evaluators; it is postulated that these responses could be due to misunderstanding the questions in the survey instrument, or due to gaps in the evaluator's knowledge of the heuristics. The latter explanation is given further credibility since complex problems that involve cognitive aspects, are supported in the pedagogy under heuristics 1, 2, 3, 4, 4.1, 5, 6, 6.2 and 7.

Lastly, the focus groups gave a more measured response regards the feasibility of the heuristics to be implemented in a high-school environment. Focus Group 2 did not respond to this question since they became distracted by a discussion on the feasibility of implementing the e-learning software within a high-school environment. Focus Group 1 offered responses across a continuum; one evaluator commented that *"it's easy if teachers have the right technology and the appropriate training and motivation for supporting it in the correct way"*. Another evaluator commented that the heuristics should be focused in areas the school is having difficulties in. Another evaluator commented that:

*"There are a lot of them, and they sometimes compete or contradict each other. This is fine, but busy teachers are not going to be able to remember the full set. Perhaps a condensed version, including the most important/beneficial heuristics, or a flowchart that can be followed easily, would make them more useful."* [Evaluator 1]

The last feedback is particularly relevant since it was identified in previous research phases and supported in the e-learning pedagogy document by the addition of a heuristic summary table, an educational benefits matrix, a heuristic relationship diagram and a detailed heuristic relationship matrix.

## **B PHASE 1 AND 2 – FINDINGS FROM STUDENT USAGE OF E-LEARNING SOFTWARE PROTOTYPE**

Chapter Six, and specifically section 6.5 of the thesis presents abridged findings from student usage of the e-learning software prototype. The findings are grouped thematically and represented in the thesis in summary table form (tables 30 through 45). This appendix follows the same thematic groupings and elaborates the Phase 1 and 2 findings with qualitative description and descriptive statistics.

## B.1 Usability and Navigation

The investigation of usability and navigation was carried out in Phase 1 and both cycles of Phase 2.

### B.1.1 Ease of Use

With reference to Figure 3, relating to whether the e-learning software is easy to use, the feedback in Phase 1 was broadly positive, with scope for improvement. Between Phase 1 and Phase2-Cycle1, a usability review resulted in usability and interface changes to the software. These changes are likely attributable for the improved student response in Phase2-Cycle1 in which all students either agreed or strongly agreed that the e-learning software is easy to use. This positive feedback was also reiterated in Phase2-Cycle2.

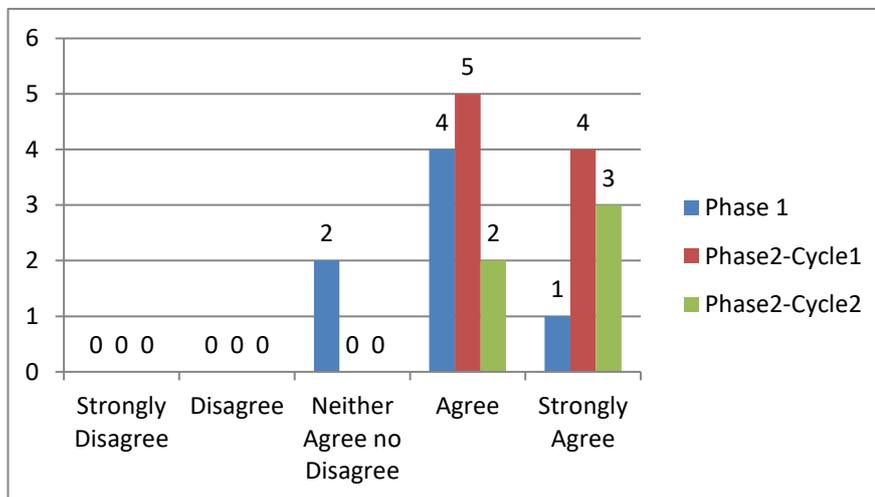


Figure 3: Phase 1 and 2 - The e-learning Software is easy to use.

### B.1.2 Reliable

Although perceived as easy to use, an area of concern that showed a negative trend through the phases was that the students perceived the e-learning software as not reliable. With reference to Figure 4, weakly positive feedback in Phase 1 became negative in Phase2-Cycle1 and did not recover in Phase2-Cycle2.

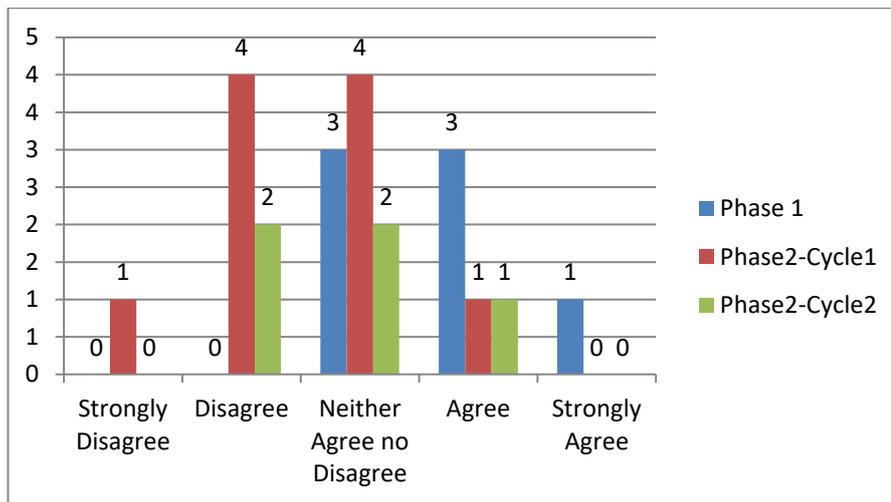


Figure 4: Phase 1 and 2 - The e-learning software is reliable (i.e. does not contain bugs or errors).

As the software became more sophisticated, in particular in its pedagogical implementation, less of the IDE’s standard outputs and functionality could be used and more bespoke development and workarounds where necessary, this, in turn, led to an increase in bugs and usability concerns that were not identified and resolved during the testing.

In **Phase 1**, the main source of concern was poor support of the software within Google Chrome web browsers, some minor bugs and a usability issue in the drag and drop activity. The issues in Chrome web browsers related to issues in the standard output of the IDE and the usability issue in the drag and drop activity related to a lack of customizability in the activity via the IDE.

In **Phase 2-Cycle 1**, based on the survey feedback the main usability concerns were:

- Audio getting out-of-synch in certain areas and the mute function not working always,
- Sluggish and choppy animation on the drag and drop activities,
- The ability to show all sentences in a slide with the press of a button if you read faster than the bullet points can appear,
- Hovering over the area where the orange text will appear shows the extra information even before the orange text appears,
- Forward button not working if the next slide is a quiz which has already been completed, meaning the user has to use the table of contents to progress,
- A usability request to have the mouse wheel work on the e-learning table of contents.

When discussed in the focus groups, one student expressed the view that the software did not feel polished; the students reiterated points from the survey feedback, such as:

- Audio getting out-of-synch in certain areas and the mute function not working always,
- Sluggish and choppy animation on the drag and drop activities,
- Functional issues with the drag and drop activities.
- Hovering over the area where the orange text will appear shows the extra information even before the orange text appears.

- The pencilcode website that is linked to by the e-learning software crashed for one student.

In **Phase2-Cycle2**, again some bugs slipped past the testing and into the version of the software used by the students. However, it is interesting to note, that some of the usability issues the students reported in the survey were actually part of the design of the e-learning software (refer to points 1 and 4 below).

1. *“when i progressed on the first level and clicked the arrow to go to the next quiz it completely skipped the quizzes and went to the end telling me I havent passed any quiz.”* [Student25]
2. *“Some quizzes in the White Belt class bugged out after hitting the reset button.”* [Student13]
3. *“It is extremely irritating when you are trying to place a piece of text (like in the pasta time management quiz) into a specific area, and it doesn't allow you to place it until you put it in a very specific place.”* [Student14]
4. *“In the last exercises if a mistake is made twice, no more changes can be made.”* [Student18]

This is taken as a note that some of the instructional design choices for the quiz activities need to be revisited and some made more explicit to the learner. For example, for quiz activities the number of allowed attempts, the current attempt and whether a quiz is locked since maximum attempts has been reached needs to be clearly shown on screen.

### **B.1.3 Navigation and Program Control**

With reference to Figure 5, in Phase 1, five of seven students agreed that the navigation is logically arranged and consistently used. The remaining students were either indifferent or did not agree that the navigation is logically arranged and easy to use. Additionally, during the focus group, the students commented that the screens should not be time-limited and not having duplicate controls on the screen or duplicate player controls.

Based on the the findings of Phase 1, the Phase2-Cycle1 pedagogy and e-learning software were updated in terms of usability and navigation. Thereafter, in Phase2-Cycle1 all students either agreed or strongly agreed that the program controls of the e-learning software were logically arranged and consistent. This was also reaffirmed in Phase2-Cycle2, with all students agreeing or strongly agreeing with the same statement.

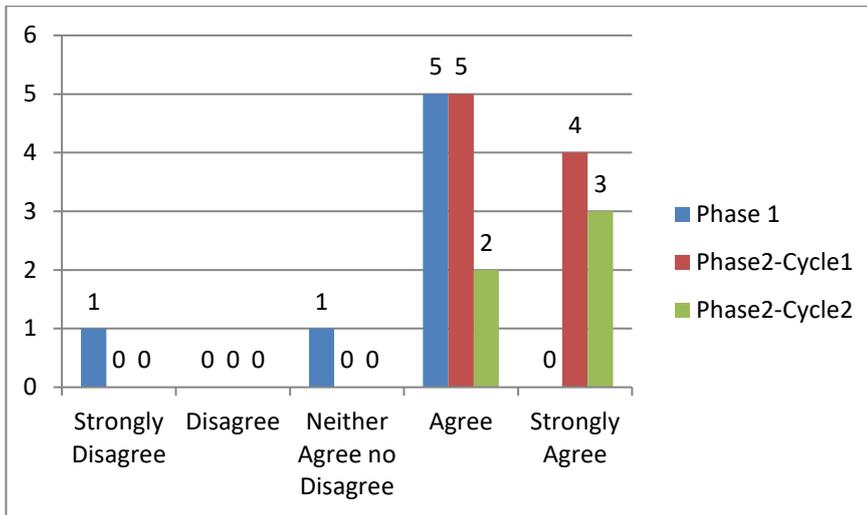


Figure 5: Phase 1 and 2 - The navigation and program controls of the e-learning software are logically arranged and consistent.

With reference to Figure 6, relating to whether the navigation and program controls are easy to use; the student response across Phase 1 and 2, were almost identical to the previous question.

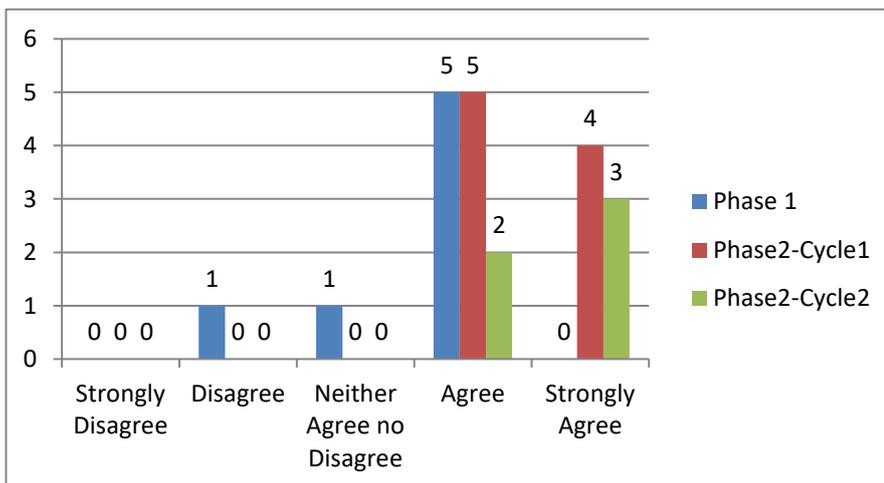


Figure 6: Phase 1 and 2 - It is easy to use the navigation and program controls of the e-learning software.

Phase2-Cycle2 reaffirmed the Phase 1 and Phase2-Cycle1 results; overall, the feedback across Phase 1 and 2 give strong positive support for Phase2-Cycle2 heuristics 21 and 21.1 related to restricted navigational control. This was explicitly discussed during both Phase2-Cycle1 focus groups, in which the students clearly voiced support for the restricted navigation approach. When asked to expand on this point one year-4 student advised: maybe we would like the greater navigational freedom to jump ahead, but it is better not to do it since we won't be able to understand if we jump forward. Another student advised that this kind of freedom may be good, but not in this case where you have to build your learning step by step.

### B.1.4 Table of Contents

During the Phase 1 focus group, there was interest in a retractable navigation tree, but that other than the next activity, future activities should be inaccessible. The main feature of the navigation tree is to be able to quickly jump back to screens the students have already visited.

Within the guidelines of the restricted navigation approach proposed by the pedagogy, a navigation tree was implemented for Phase2-Cycle1. The restricted navigation tree shows progress, what learning activities are ahead and allows navigation to the next screen and all previously completed screens. In Phase 2-Cycle 1, this navigable tree received almost universally positive feedback in the survey (refer to Figure 7) and focus groups. One year-5 student enthusiastically advised that it was the “*best addition - one of the most noticeable changes.*”

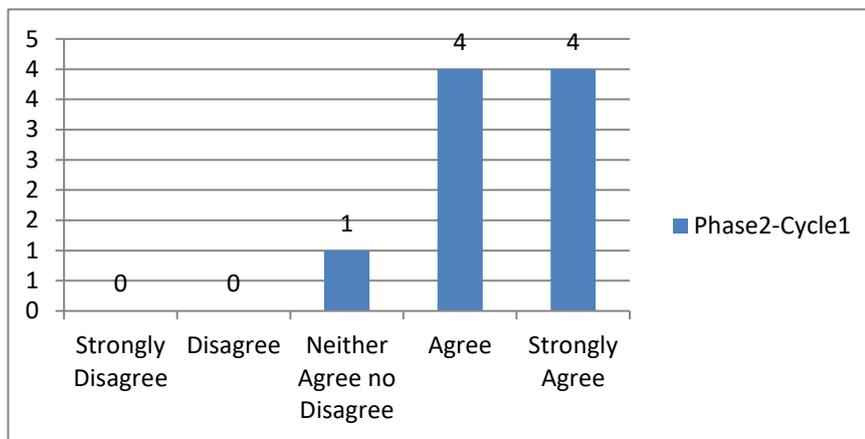
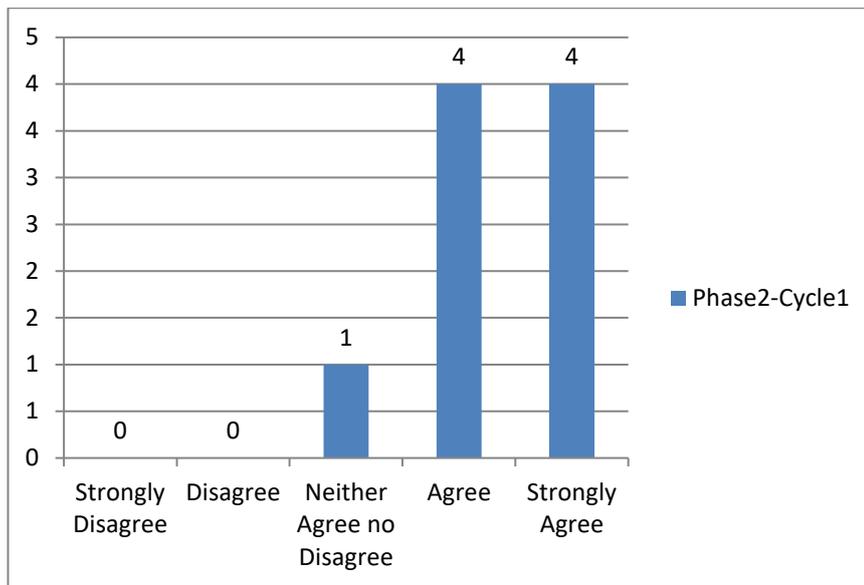


Figure 7: Phase2-Cycle1 - The navigation tree provides additional benefit in navigation and program control.

### B.1.5 Instructions and Prompt Messages

In Phase2-Cycle1, contrary to the reasonably positive results showing that five students agree, and two students strongly agree with the statement “*The various instructions and prompt messages are understandable*” (Refer to Figure 8), one significant usability issue was speculated during the observation study and confirmed in the focus groups.



**Figure 8: Phase2-Cycle1 - The various instructions and prompt messages are understandable.**

Despite the initial presentation and training at the beginning of the observation study, many of the students did not read the screen instructions and missed within-screen navigation. This had a critical impact since a number of students missed significant portions of the learning material. The volume of learning material to be conveyed and the approach to grouping learning material meant that some screens contained allot of learning material that is accessed via internal navigation buttons such as hints

 , within-screen navigation   , computational thinking  and image hotspot links.

Although these are intended to be intuitive, screen instructions are also located at the bottom of each screen to give direction to the students. It is postulated that part of the reason for these being missed was that during the research study the students knew their learning would not be tested therefore their intrinsic incentive was to complete as much as possible, not to learn as much as possible, this potentially led them to rush. During the focus group, the students advised that the screen instructions were too faint and easy to miss. This was, in fact, an intended design to differentiate them from learning content, but it is clear that the screen instructions must be made more prominent to the students. The year-4 students made a number of suggestions on how to make the screen instructions more attention grabbing:

1. Make instructions bigger, bolder, or in red text,
2. At the end of the screen audio, prompt the students to read the instructions, or
3. Include the screen instructions in the screen audio.

Another area in Phase2-Cycle1 that had room for improvement was the Learning Object Icons that signpost to students what types of learning content is represented on each screen. Overall, the balance of opinion was that these icons provide useful information, but similar to the screen instructions they were not noticeable enough. For the most part, this was due to an intentional design decision to keep them unobtrusive, but it is clear from the student response that there is an opportunity to make them

more prominent. In addition, it was suggested that rollover tooltips could be used to make it clear what each icon represents.

In Phase2-Cycle2 to mitigate the above issue: important buttons were animated to enlarge and highlight them to draw the students' attention, important screen instructions were animated to blink, with the aim of drawing the students' attention, and learning object icons were enlarged.

The results in this area were weakly positive, three from five students agreed or strongly agreed with the statement *"The animations to enlarge and highlight important buttons and within screen navigation, helped me to focus on the essential learning material"* (refer to Figure 9). Furthermore, three from five students agreed or strongly agreed with the statement *"The blinking text on important screen instructions helped me to focus on the essential learning material"* (refer to Figure 10).

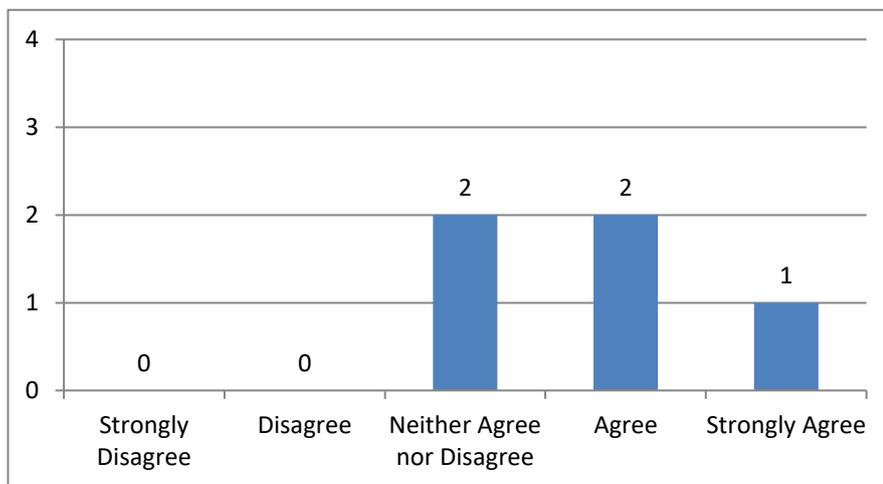


Figure 9: Phase2-Cycle2 - The animations to enlarge and highlight important buttons and within screen navigation, helped me to focus on the essential learning material.

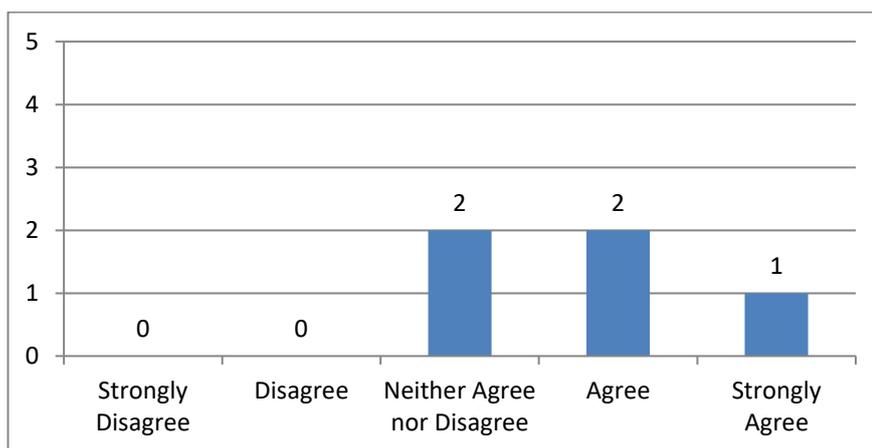


Figure 10: Phase2-Cycle2 - The blinking text on important screen instructions helped me to focus on the essential learning material.

Discussion during the Phase2-Cycle2 focus group confirmed the weak support; all students agreed the animation of important buttons and instructions benefited them by drawing their attention. However, it did not necessarily mean they would read the instructions; two students commented:

*“but if you think you know what you’re going to do, you won’t read it. I personally if I thought I knew what to do I would not.”* [Student 25]

*“If you check the screen and are interested and think you know what to do, even if you notice it blinking at the bottom you might still ignore it and say I don’t care I know what to do. But it’s always good if it blinks.”* [Student 19]

Additionally, one student commented that adding more colour (red) to the instructions would help and one student suggested that the button and instruction animations should continue until the user explicitly clicks on them.

In Phase 2-Cycle 2 a pre-training video was included to introduce the students to the e-learning software and Collaborative Learning Environment (CLE). This was in response to feedback in Phase 1 and Phase2-Cycle 1, and in alignment with heuristic 19. During the observation study, the students did not seem to be particularly attentive to this video. One potential reason for this is that the video was over 7 minutes long with a variety of material on how to use the software and CLE. In hindsight, heuristic 18 guideline-8 and heuristic 17.1 guideline-2, which relate to keeping text and audio concise and focused also apply to video; the video in its current form was too long and multi-focused. A better approach was to split the long video into focused mini-tutorials on specific areas. The students aligned with this approach and went further to suggest that tutorials should not be given at the start but spread as needed across the software screens.

*“I think instead of having the video at the start I think it’s easier for the person who hasn’t seen it to keep going and for each slide to have a popup explaining this is the table of content this is the navigation buttons.”* [Student25]

*“Sort of like a tutorial, it’s showing you what you can do the first time and then can click and exit it to disappear or go away ... I don’t know.”* [Student14]

*“Most people ignore tutorials at beginning, so maybe where you have a link to Collaborative Learning Environment; you give them link to tutorial at that point ... maybe on the platform you could create a tab there where people could access the tutorials.”* [Student18]

Overall, Phase 2-Cycle 2 offered a slight improvement over Phase2-Cycle1, regards the students understanding of the various instructions and prompt messages. Three students agreed, and two students strongly agreed with the statement that *“the various instructions and prompt messages are understandable”*.

## **B.2 Learning Styles and Multi-modal Learning**

The investigation of learning styles and multi-modal Learning was carried out in Phase 1 and Phase2-Cycle1. As discussed in section 2.4.7 of the thesis, it is theorised that all students have different preferences in the best way they perceive new learning material, but overall the best way to reach the students is to use varying methods (modalities) to represent the same educational concepts. The students’ modal preferences were measured in the VARK questionnaire. It should be noted that the student

participants from Phase2-Cycle1 incorporated six students from Phase 1, and three new year-4 students joining in Phase2-Cycle1. As such, the overall values in Phase2-Cycle1 are slightly higher since the values are based on nine respondents instead of eight. Figure 11 counteracts this by converting the VARK responses to percentage values that can be more easily compared.

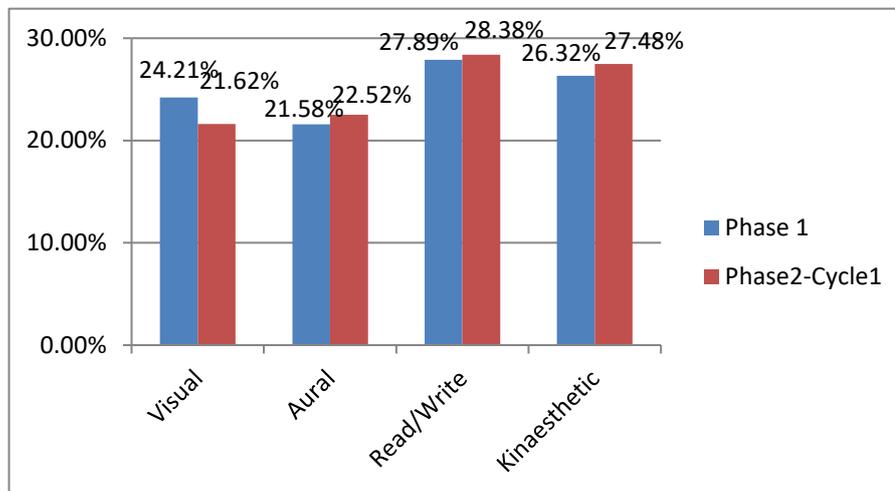


Figure 11: Phase 1 and Phase2-Cycle1 - VARK modal preferences for students.

We see a very small shift in modal preference between visual and aural between Phase 1 and Phase2-Cycle1, some bias towards read-write and kinaesthetic in both phases; however, overall in both phases, there is comparative balance between the modalities. This offers broad support for the multi-modal approach outlined in heuristic 16, but as with other quantitative results in this section, the small number of participants means we cannot ascribe statistical significance to these results; this will be addressed in Phase 3.

The tentatively positive indicators towards multi-modal learning are reinforced in Figure 12, which reflects the questionnaire feedback on whether *“The approach of using varying methods to represent the same educational concepts helped my understanding.”* In both Phase1 and Phase2-Cycle1, all students either agreed or strongly agreed multi-modal approaches helped their understanding.

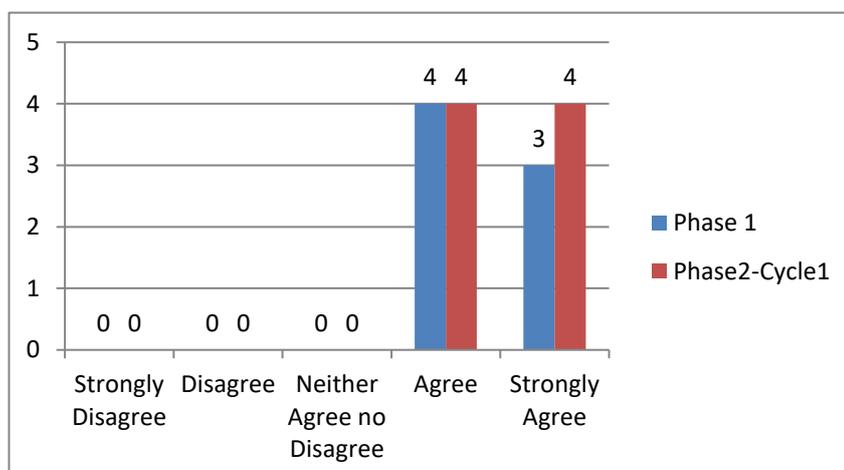


Figure 12: Phase 1 and Phase2-Cycle1 - The approach of using varying methods to represent the same educational concepts helped my understanding.

An interesting point that gives support to heuristic 16 is that the instructional designer for the e-learning software has a dominant read-write modal preference (refer to Figure 13). In violation of heuristic 16, the instructional designer did not actively manage this dominant modal preference and created e-learning software with a heavy text bias. This was clearly represented in the negative feedback from the students in Phase 1. Refer to section B.8, which discusses the student feedback and how it was addressed in later phases.

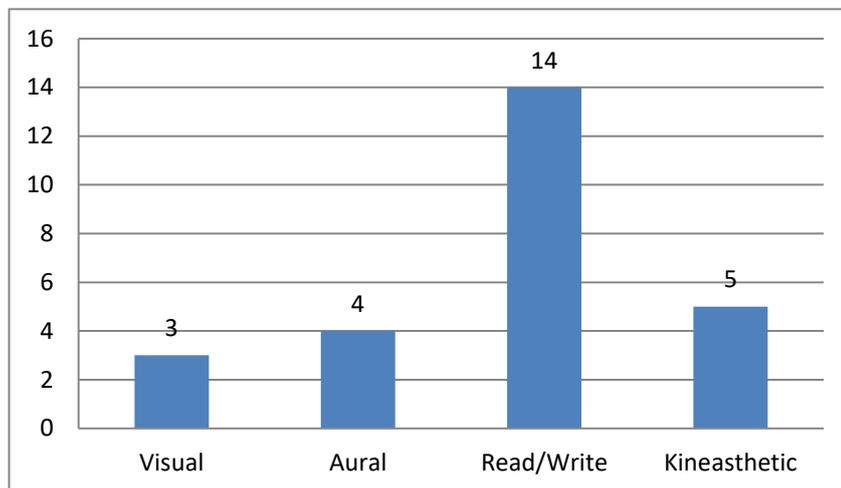


Figure 13: VARK modal preferences for the instructional designer.

### B.3 Understanding and the Zone of Proximal Development

The investigation of student understanding, and the zone of proximal development was carried out in Phase 1 and both cycles of Phase 2. In addition, in Phase2-Cycle2 there was an increased focus on student assessment within the e-learning software.

With reference to Figure 14, in Phase 1, five of seven students either agreed or strongly agreed that the educational material in the e-learning software was represented in a clear and understandable way. In both cycles of Phase 2, all students either agreed or strongly agreed that the educational material in the e-learning software was represented in a clear and understandable way.

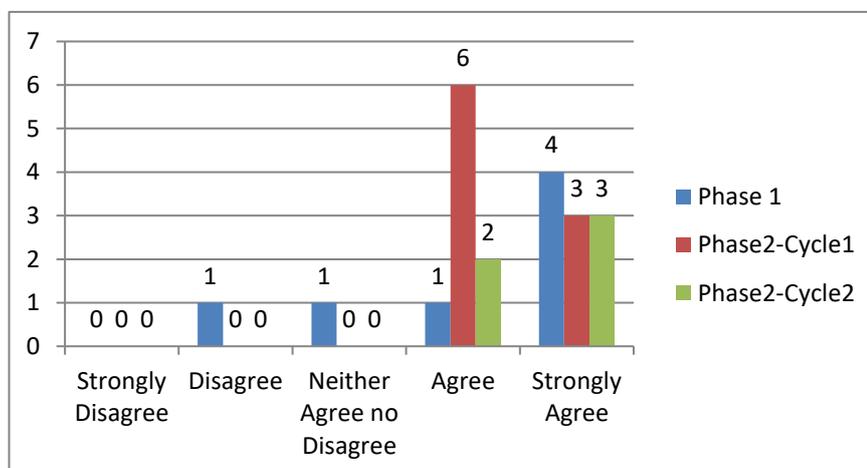


Figure 14: Phase 1 and 2 - The educational material was represented in a clear and understandable way.

This is self-reported feedback and does not equate with learning, but does give a positive indicator of the value of the pedagogical heuristics and in particular heuristics 1, 4.1, 7, 7.1, 8, 16, 16.1, 16.2, 16.3, 16.4, 17, 18, 19, 20 and 21.1.

However, we should note that in Phase 1 some students (two of seven) still felt they would need to supplement the e-learning software with further textbook reading. In Phase2-Cycle1, none of the students responded that they supplemented, or needed to supplement, the learning material in the e-learning software with further textbook reading, and in Phase2-Cycle2, all but one student **strongly disagreed** with the statement (refer to Figure 15).

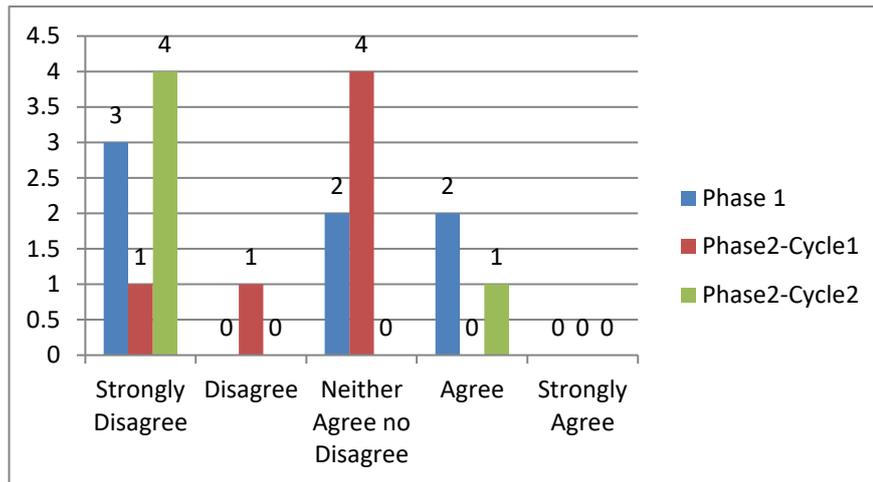


Figure 15: Phase 1 and 2 - I supplemented, or needed to supplement, the educational material in the e-learning software with further textbook reading

In keeping with heuristic 10, relating to the zone of proximal development, the difficulty of e-learning software is targeted a little ahead of the students' current stage, i.e. "A Little Difficult."

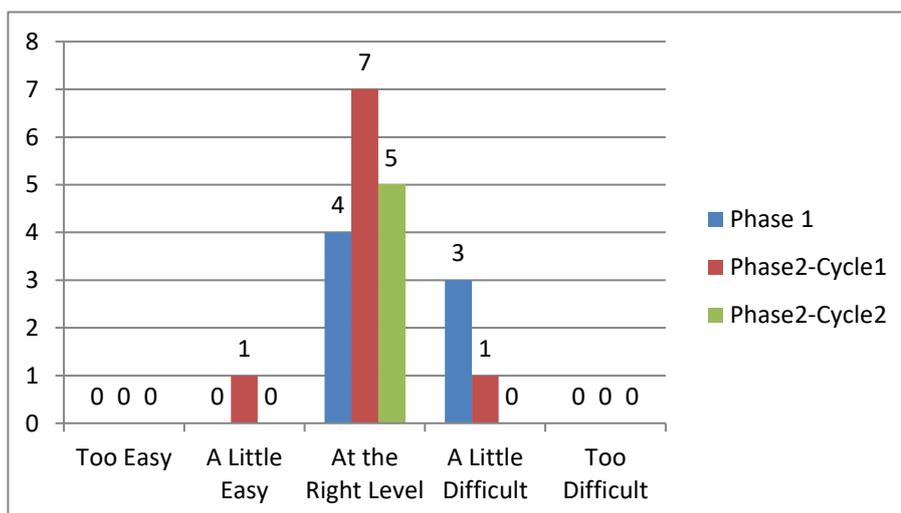
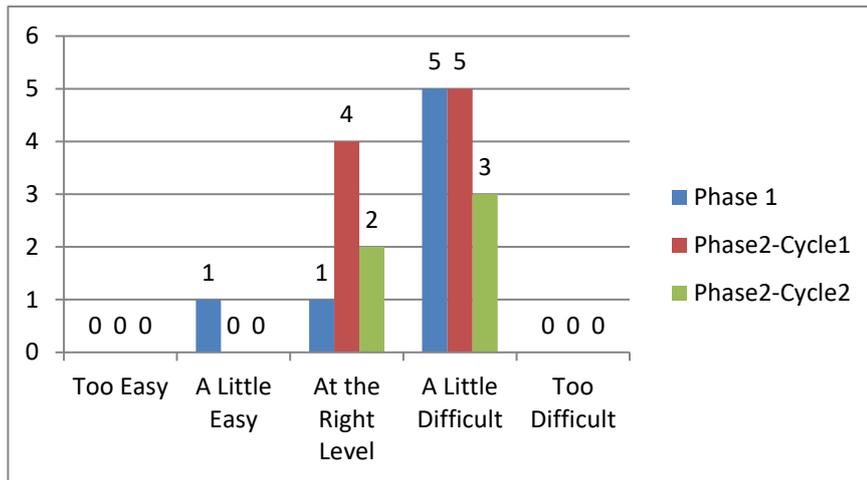


Figure 16: Phase 1 and 2 - Difficulty level of educational material in the e-learning software.

With reference to Figure 16, the students perceive the difficulty level of the e-learning content to be split between being at the right level and a little difficult, although the trend in Phase 2 was towards at the right level. Speculatively, this could be explained by the fact that all students had used the e-learning

software before and would understandably find the material easier. Overall, this is reasonably positive, considering that almost all these students were “A” grade students.

With reference to Figure 17, the students’ perceived the difficulty level of the assessment activities to be split between being at the right level and a little difficult; however, the split was more biased towards being a little difficult. In Phase2-Cycle2, this can be partially explained since new quiz activities were introduced that the students had never seen and therefore assessed to be more difficult. This is again reasonably positive, but considering that almost all of these students were “A” grade students, consideration was given to slightly reducing the difficulty level.



**Figure 17: Phase 1 and 2 - Difficulty level of the assessment activities.**

Although positive, the previous findings on perceived difficulty and the students’ perception of their level of preparedness (refer to section B.7) are self-reported feedback and do not equate with learning; in fact, when triangulated with the students’ learning performance in quiz results they offer contradictory findings.

In Phase2-Cycle2, more focus was placed in measuring student learning performance. Before undertaking the observation study, the students were informed that they would cover less learning material (two levels), but that their quiz responses would be recorded and evaluated. In the survey instrument when asked “How did the above information make you feel?” the students responded broadly positively:

*“I felt that i had to focus on learning the material very deeply so i could make a good attempt on the quiz.”* [Student25]

*“Pleased and relaxed as the learning material was less and more centered.”* [Student19]

*“I don't mind doing less work and I don't mind having my work recorded either, so I reacted positively.”* [Student13]

*“It made me feel like it would be less stressful to complete the assignments since they were given out in two different sessions. The fact that the responses were recorded and evaluated didn't affect me in any way.”* [Student14]

*“I thought positively about it as there was a goal.”* [Student18]

The students were then asked “*Did the above information affect the way you approached the e-learning software. If yes, how?*” which led to the following responses:

*“it did not because it didn't matter to me how many levels i could cover but if the materials where helpful.”* [Student25]

*“Yes, a little, by making me focus more on each slide, as this time there was a similar amount of information per chapter, but in less slides and more centered, forcing more of my attention to each individual slide of the software.”* [Student19]

*“No”* [Student13]

*“Not really, I saw the software as I did before and gave the same amount of effort as before.”* [Student14]

*“Yes. I took the quizzes and the assignment more seriously.”* [Student18]

Overall, the findings from the survey and the follow-up focus group indicated that having their learning performance measured did not negatively impact how the students’ felt about the study and either did not change how they approached the software or in a few students motivated them to give additional focus to the learning material.

The “*Level 1 White*” e-learning software focused on the underlying theory and terminology of algorithms and computational thinking with the aim of providing the students with a theoretical foundation before moving to advanced levels in which they focused on more interactive active learning. There were three quiz questions in this level (refer to Table 1), which were primarily based on student recall of terminology and concepts.

Num	Question Type	Description	Points
W1	Matching question	Correctly match the name of a Computational Thinking concept with the concept description.	60
W2	Multiple selection	Select the Computational Thinking approaches from the provided options	50
W3	Fill in the blanks	Fill in the blanks to give the correct meaning to the paragraph about Algorithms.	50

**Table 1: Phase2-Cycle2 - Summary of level 1 quiz questions**

Based on the survey findings the students were broadly positive towards the new quiz questions, with some reservations:

*“the positively impacted my learning assessment as i had to read the content several times as well as think myself what i should answer.”* [Student25]

*“Positive, short questions at the proper amount of difficulty, making you think, and not wasting time typing large answers. Straight to the point.”* [Student19]

*“They helped, but not as much as the coding questions like the one with the grid.”* [Student18]

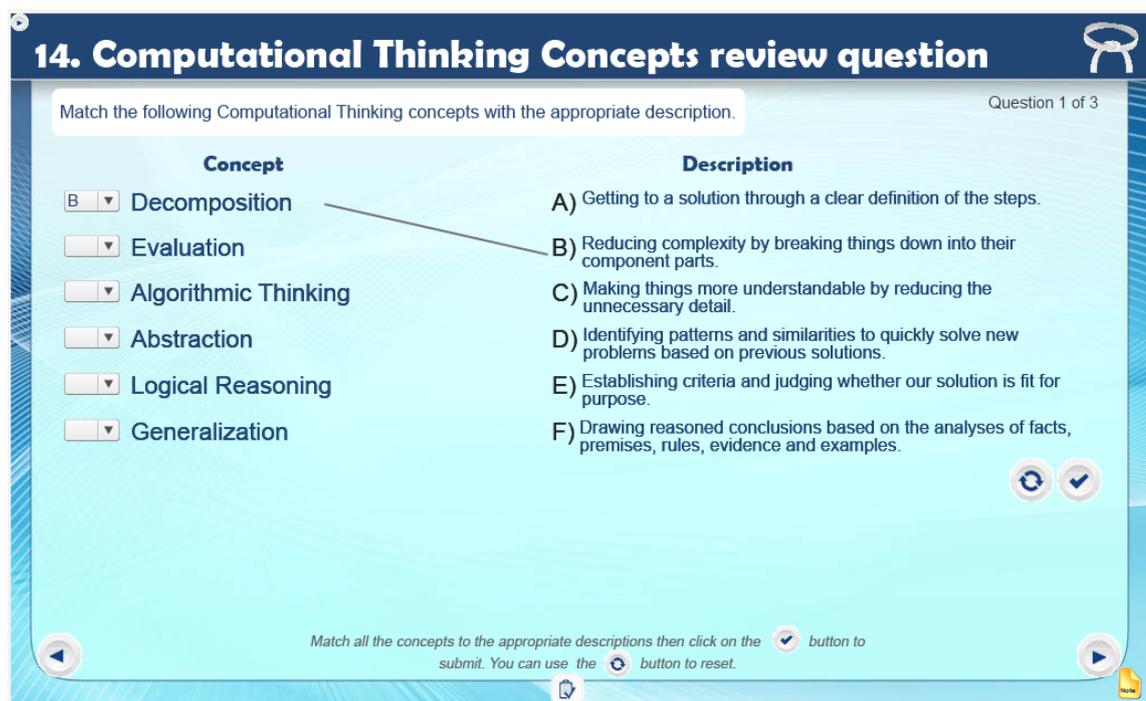
*“...Overall, they were fun to complete and weren't too challenging.”* [Student14]

*“Since variety is good they were a pleasant addition. However I doubt that they had any tangible benefit over other types of exercises.” [Student13]*

Contrary to the students’ feedback on the new quiz questions and the perceived difficulty level of the e-learning software, the learning performance on the quiz questions was very weak. Of seven students, only one received a pass mark with 69%, two received 45%, and the remaining four students did not answer any questions correctly. The contributing factors to this result are discussed for each question.

Question W1 (refer to Figure 18) is new to the students but was not reported as being a difficult question, in the focus group one student commented that:

*“For me i think it was a really good exercise, because it’s a really easy way to describe what you have actually learnt, you can’t guess in this scenario and it’s the basics of computational thinking. It’s a basic quick test, quick quiz in an easy format to see if you’ve actually learnt.” [Student19]*



**Figure 18: Quiz question W1 matching question.**

Of the five students attending the focus group, only one successfully answered this quiz question correctly; however, a few students commented that they only got one statement wrong. During the focus group, a critical factor reported by the students was that they knew the information, and matched almost all statements correctly, but failed the question since all statements had to be correctly matched.

*“It should not be whole question; it should be you have 10 statements you got 8 right it should be 8 out of 10. Not completely zero.” [Student25]*

Unfortunately, this is a limitation of the e-learning development environment, which does not support partial and negative scoring on this question type.

The survey instrument offered mixed findings related to restricting the number of attempts at a quiz question; this mixed feedback was confirmed during the focus group. A number of students complained that they only received two attempts to answer the question and would have preferred unlimited attempts.

*"i didn't think it was needed because trial and error is sometimes needed in some cases."* [Student 25]

*"I think that there shouldn't be a restriction to the number of attempts, in order to give the student the option to try to find the answer on his own, and see the answer if he wants to after a number of tries. It didn't really allow me to try a large variety of answers in order to see what the question was exactly looking for when I wasn't sure."* [Student14]

*"I think it shouldn't be restricted as someone can make a typo or accidentally put the wrong answer, so I think it's better to just decrease the score of each assessment by a certain amount for every next try."* [Student18]

Other students were more positive towards restricting attempts:

*"I believe this was right, as if you did not manage to complete the quiz in 1-2 tries, it means you don't know the answers, and after that you're just guessing and just playing around until you find the answers."* [Student19]

*"They weren't difficult enough to make this a problem, so it didn't really have an impact."* [Student13]

An interesting factor brought up during the focus group was that despite being prompted by the e-learning software to go back and review material and on the final attempt being navigated back to the relevant material. The students chose to guess on their last attempt, rather than re-review the material to guarantee they would get the question right. When navigated back to re-review the learning material one student commented that:

*"so I skipped the slides (pressed next next next) again, not skipping, I just went one by one... I did this so I wouldn't have to repeat it all."* [Student18]

This tactic of guessing on the last attempt could have many potential root causes based on personality, age and risk tolerance etc., but one theory is that the students remain aware that this is a research study and that answering a question fully correct or almost correct has limited impact and importance to them. In Phase 3, when the e-learning software is integrated into the GCSE instruction, this factor is postulated to be reduced.

One final contributing factor to the students' poor learning performance is that this study was set directly after the students' end of year exam period and a number of the students were visibly fatigued.

*"I think this is purely our problem cause we just weren't awake."* [Student14]

Question W2 (refer to Figure 19) is new to the students and is a straightforward question to identify and select the approaches common in computational thinking.

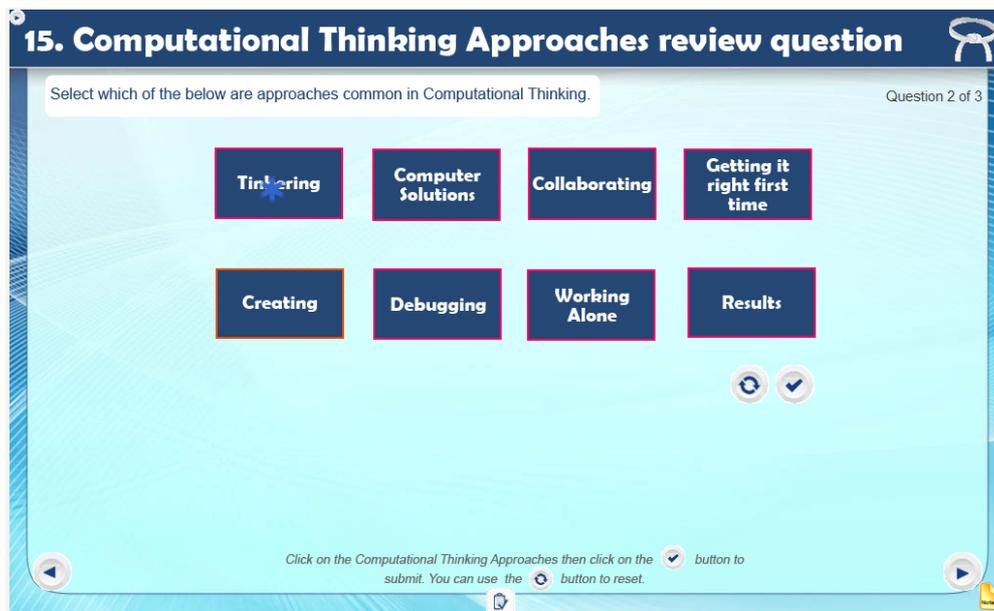


Figure 19: Quiz question W2 multiple selection.

From seven respondents only three got this question correct. This question was also impacted by the same factors discussed in question 1.

Question W3 (refer to Figure 20) is new to the students and requests that they fill in the blanks on a paragraph that describes algorithms. None of the seven students answered this question correctly. This question was also impacted by the same factors discussed in question 1, however, was impacted more significantly by poor instructional design. This was raised in the survey findings and confirmed in the focus group:

*“Moreover, a fill in the blanks question is not always ideal because it does not accept valid synonyms.”*  
[Student13]

*“They were pretty interesting to complete, however the fill in the blanks exercise should have a word box at the bottom in order to help you understand which words need to be filled in.”* [Student14]

This question relied heavily on students recalling exact wording and terminology and offered limited synonyms; this in combination with a lack of partial marking meant none of the students was able to fill in all the blanks correctly. This question would be very difficult to answer even for someone with good knowledge in this area and in its current form is an unreasonable measure of student learning

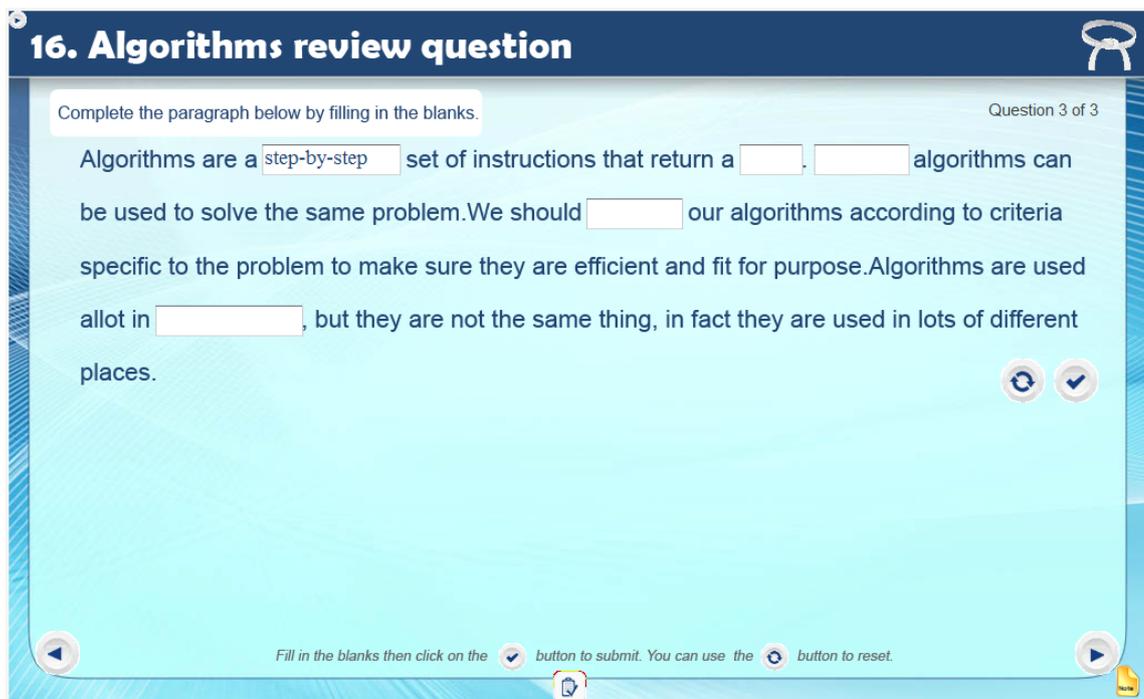


Figure 20: Quiz question W3 fill in the blanks question.

The “Level 2 Yellow” e-learning software focused on determining the purpose of algorithms, explaining them in terms of inputs, processing and outputs and recognising and understanding elements of computational thinking. There were six quiz questions in this level, which were primarily focused on active learning (refer to Table 2).

Num	Question Type	Description	Points
Y1	Drag and drop	An easy quiz question to warm the students up to the activities. Students drag and drop the 3 boxes (Algorithm Steps, Input, Output) to the appropriate section of the recipe.	30
Y2	Drag and drop	A real-life scenario to sequence and schedule parallel work activities to prepare for a dinner party.	100
Y3	Multiple selection	Abstraction exercise for students to select all information relevant for an online university application	80
Y4	Multiple selection	Abstraction exercise for students to select all information relevant for a social media website.	120
Y5	Drag and drop	Introductory exercise for students to correctly sequence structured English algorithm steps.	50
Y6	Multiple choice	Based on given inputs and algorithm, calculate the correct output value.	40

Table 2: Phase2-Cycle2 - Summary of Level 2 quiz questions.

Question Y1 (refer to Figure 21) was included in previous versions of the software and is a relatively straightforward question to identify the inputs, algorithm steps and outputs of a recipe. All students answered this question successfully.

## 5. Quiz Algorithm Inputs, Processing and Outputs

Some more examples of common everyday algorithms are giving route directions, knitting patterns and instructions for flat-pack furniture. Lets look at another algorithm in a bit more detail. Maybe you have never considered it before, but a recipe is an algorithm. Each Algorithm has inputs, the steps used for processing and outputs.

Please drag and drop the below algorithm elements onto the appropriate part of the Baked Ziti recipe.

### Baked Ziti



Serves: 10 [change](#)

Prep Time: 35 Minutes

Cook Time: 20 Minutes

Ready In: 55 Minutes

**ALGORITHM  
STEPS**

**INPUT**

**OUTPUT**





#### Ingredients

- 1 pound dry ziti pasta
- 1 onion, chopped
- 1 pound lean ground beef
- 2 (26 ounce) jars spaghetti sauce
- 6 ounces provolone cheese, sliced
- 1 1/2 cups sour cream
- 6 ounces mozzarella cheese, shredded
- 2 tablespoons grated Parmesan cheese

#### Directions

1. Bring a large pot of lightly salted water to a boil. Add ziti pasta, and cook until al dente, about 8 minutes; drain.
2. In a large skillet, brown onion and ground beef over medium heat. Add spaghetti sauce, and simmer 15 minutes.
3. Preheat the oven to 350 degrees F (175 degrees C). Butter a 9x13 inch baking dish. Layer as follows: 1/2 of the ziti, Provolone cheese, sour cream, 1/2 sauce mixture, remaining ziti, mozzarella cheese and remaining sauce mixture. Top with grated Parmesan cheese.
4. Bake for 30 minutes in the preheated oven, or until cheeses are melted.

Click on the  button to submit your answer, the  button to undo last action or the  button to reset.

Figure 21: Phase2-Cycle2 - Quiz question Y1 drag and drop.

Question Y2 (refer to Figure 22) was included in the previous versions of the software and is a more complex exercise to sequence and schedule algorithm steps across parallel work streams. Due to the increased challenge of this exercise, the students were given three attempts to complete it. From seven students, one successfully answered the question, two students did not answer correctly, and four students did not attempt the question. The poor results for this question were attributed to two main factors. Some of the students could not relate to the scenario to prepare for a dinner party and were not sure of the necessary steps. This point was raised in previous cycles and in the Phase2-Cycle2 survey findings

*"... However the question where you had to 'prepare dinner' felt irrelevant."* [Student13]

In the focus group, this was discussed at length. It was commented that there are already numerous hints to help the students with the sequencing of steps. Additionally, to help the students visualise the activities, it was agreed that in the next version of the software for each draggable item, hovering over it would show an image of the activity. When asked to vote on whether the scenario for this exercise should be replaced with something different, four from five students agreed that it should remain as is. The students were also asked to suggest an alternate scenario that would be of interest to them; there were two suggestions "video editing" and "a typical day at school." The first suggestion was discussed that it is possibly not appropriate for the target GCSE audience since it requires a high level of domain knowledge. Potentially a bigger concern for this question is the drag and drop controls were considered frustrating, since they require the user to be very precise or the draggable item drops into the wrong place. One student acknowledged that he became so frustrated with this that he gave up answering the question. This student also reported it in the survey findings:

*"Irritating control over certain elements of the exercises (moving text boxes)."* [Student14]

The issue with the drag and drop controls has been steadily improved over the different versions, but it is acknowledged that it needs a more significant update to improve usability.

### 6. Quiz Algorithm Steps

You are throwing a dinner party for some friends and you plan to start eating at 20:00 sharp. You are cooking your great grandmother's traditional pasta recipe in which you boil the pasta separately and cook the mince meat and sauce together before mixing them all together at the end to simmer.

Please sequence and schedule the cooking and table setting activities to make sure your dinner party successfully starts at 20:00 with hot pasta.

	Cook Pasta	Cook Pasta Sauce	Set the Table
19:30	Boil water (5 min)		
19:35		Brown mincemeat (10 min)	
19:40			
19:45			
19:50			
19:55			
20:00	Dinner Party		

One of the longest activities in creating the sauce.

Simmer Pasta till al dente (5 min)      Mix sauce into mincemeat and simmer (5 min)

Drain excess water (5 min)      Add sauce to pasta (5 min)

Serve food (5 min)      Collect cutlery and tableware (5 min)

Mix and simmer Pasta and Sauce (5 min)      Set table (10 min)

Hover the mouse over the drop area to get a hint. Click on the button to undo the last action, click on the button to reset all and click on the button to submit. Click on the button to see more information on Computational Thinking, then click again to hide the information.

Figure 22: Phase2-Cycle2 - Quiz question Y2 drag and drop.

Question Y3 (refer to Figure 23) and Question Y4 (refer to Figure 24) are new questions which focus on abstraction by asking the students to identify the correct information relevant to an online university application and a social media profile. The two questions attempt to demonstrate to students that the same base information can be abstracted in different ways according to the specific context. An issue in the configuration of partial scoring for Question Y3 meant that the student results were inadmissible.

### 7. Quiz Question on Abstraction - Online University

Remember Abstraction is about reducing complexity by removing unnecessary detail and focusing only on what's important. The real skill is deciding what details to hide and what to focus on.

People are so complex and so much information can be stored about them; lets try and abstract away some of this complexity by focusing only on the relevant information. For an **online university application** what do you think is the relevant information? (You have one attempt to mark all the relevant information)

Question 3 of 6

- 1. Places you've lived
- 2. First and Last Name
- 3. Academic Major
- 4. Program of Study
- 5. Phone Number
- 6. Life Events
- 7. Family and Relationships
- 8. Gender
- 9. Address
- 10. Nickname
- 11. Friends
- 12. Academic Qualifications and Grades
- 13. Religion
- 14. Password
- 15. eMail

Click the button to submit your answer. Click the button to reset.

Figure 23: Phase2-Cycle2 - Quiz question Y3 multiple selection.

Question Y4 has partial scoring correctly configured; three students received 100 points from a total of 120 points, two students received 60 and 70 points respectively, and two students received 30 and 40 points respectively. During the focus group, the students accepted these questions as worthwhile activities that helped build knowledge and demonstrate abstraction, but were uncomfortable with the activities being used as quiz questions. The concern seemed to revolve around the fact that there is a perceived degree of subjectivity in answering the question.

*"I don't think it's that good of an exercise because the social networking one is sort of subjective what you are asking."* [Student25]

There seemed to be an implicit expectation from the students that there should be clear learning material, which would lead to a black and white answer. The fact that these questions required judgement on their part which could potentially lead to an incorrect quiz question troubled the students.

*"I think the next slide where it showed you the link between being a person and being a university student and being on a social network that was much clearer than having to do the exercises... [Referring to quiz questions] now that maybe isn't a good idea; maybe it should be an introduction instead of quiz question."* [Student14]

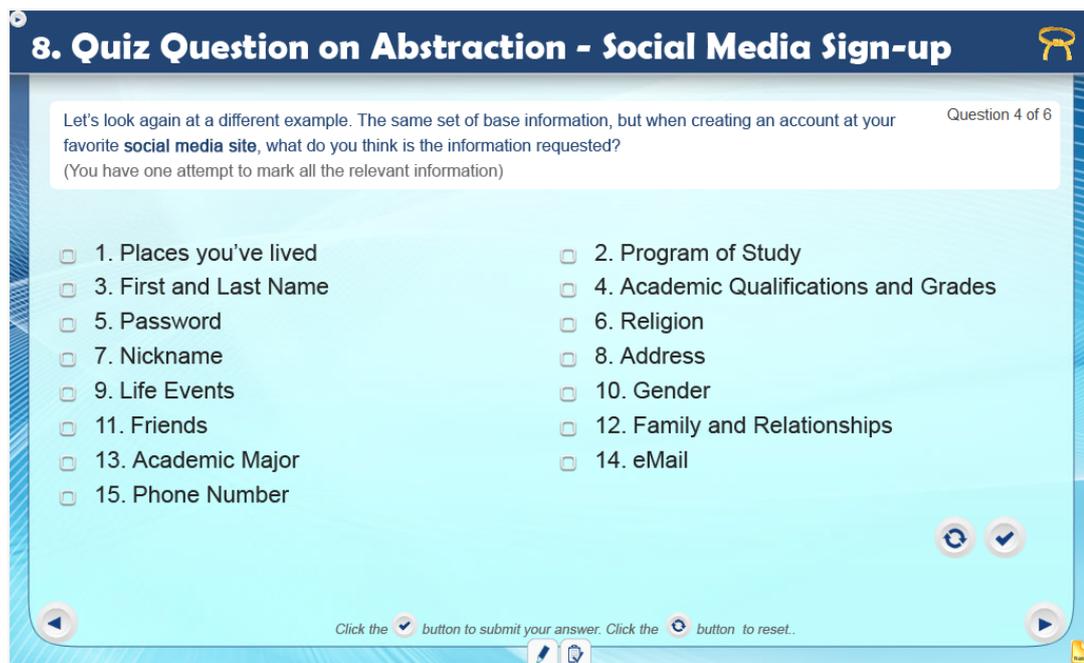


Figure 24: Phase2-Cycle2 - Quiz question Y4 multiple selection.

Question Y5 (refer to Figure 25) was included in the previous versions of the software and is a drag and drop question for students to understand structured English and sequence groups of steps into the correct sequence. Only one student answered this question correctly; however, during the observation two students complained that the software had failed their correct response. This was verified, and it was identified that a bug in Internet Explorer caused the correct response to be incorrectly marked. The student who passed the question used the Chrome web browser. Based on the observation study and

knowledge of the students it is expected that a significant portion of the students would have got this question correct.

**10. Algorithm Steps - Taxi Charge Algorithm**

```

BEGIN
SET startTime to start time of journey
SET passengerNumber to the number of passengers
SET journeyDistance to the distance of the taxi ride
SET taxiCharge to 0
IF startTime is between 21:00 and 6:59 THEN
    Set taxiCharge to £5
END IF
SET journeyDistance to (journeyDistance - 1)
Set taxiCharge to (taxiCharge + (taxiCharge * 50%))
SET taxiCharge to (taxiCharge + (£2 * journeyDistance))
END IF
PRINT "Your taxi charge is: ", taxiCharge.
END
    
```

ELSE  
Set taxiCharge to £3  
END IF

Click on the button to undo the last action, click on the button to reset all and click on the button to submit.

Figure 25: Phase2-Cycle2 - Quiz question Y5 drag and drop.

Question Y6 (refer to Figure 26) was included in the previous versions of the software and is a moderately complex multiple-choice question to walk through a given algorithm and based on input values identify the correct result. Two students got the answer correct, four students got incorrect results, and one student did not attempt. Before the students started to use the software, they were pre-warned not to answer questions based on their memory of previous versions of the software. It seems a number of students faced this challenge, a relatively small wording change in this question meant the answer was different. One student confirmed, that he made this mistake; this offers a potential explanation of why other students got this question wrong.

## 11. Quiz Question on Taxi Algorithm

Question 6 of 6

```

BEGIN
SET startTime to start time of journey
SET passengerNumber to the number of passengers
SET journeyDistance to the distance of the taxi ride
SET taxiCharge to 0
IF startTime is between 21:00 and 6:59 THEN
  Set taxiCharge to £5
ELSE
  Set taxiCharge to £3
END IF
SET journeyDistance to (journeyDistance - 1)
Set taxiCharge to (taxiCharge + (£2 * journeyDistance))
If passengerNumber is 5 or more THEN
  Set taxiCharge to (taxiCharge + (taxiCharge * 50%))
END IF
PRINT "Your taxi charge is: ", taxiCharge.
END

```

You and 4 friends are planning a night out and you've decided to take a taxi. It's a school night so the taxi is picking you up at 20:30 and you must be home before midnight. The taxi ride is 10 kilometres in each direction. Please select the total taxi charge for the evening from the below options.

- A) £46
- B) £64
- C) £44
- D) £66

Click the button to submit your answer. Click the button to reset.

Figure 26: Phase2-Cycle2 - Quiz question Y6 multiple choice.

The quiz results from Phase2-Cycle2 gave clear indicators on how to improve the question design of quiz questions that would in turn support students to demonstrate their knowledge. In addition to their comments regards the number of attempts per question, the students also expressed the opinion that the students should be able to take the quiz multiple times.

*“you should be able to redo the quizzes after seeing the material again”* [Student18 and Student25]

However, these improvements were considered in relation to the restrictions imposed by the question widgets in the development environment.

## B.4 Computational Thinking

In Phase 2-Cycle 1, a new heuristic and 2 sub heuristics were defined to *“Support Problem Solving through Computational Thinking”*. The results in this area were moderately positive, three students agreed, and four students strongly agreed with the statement *“The e-learning software helped me to understand what Computational Thinking is”* (refer to Figure 27).

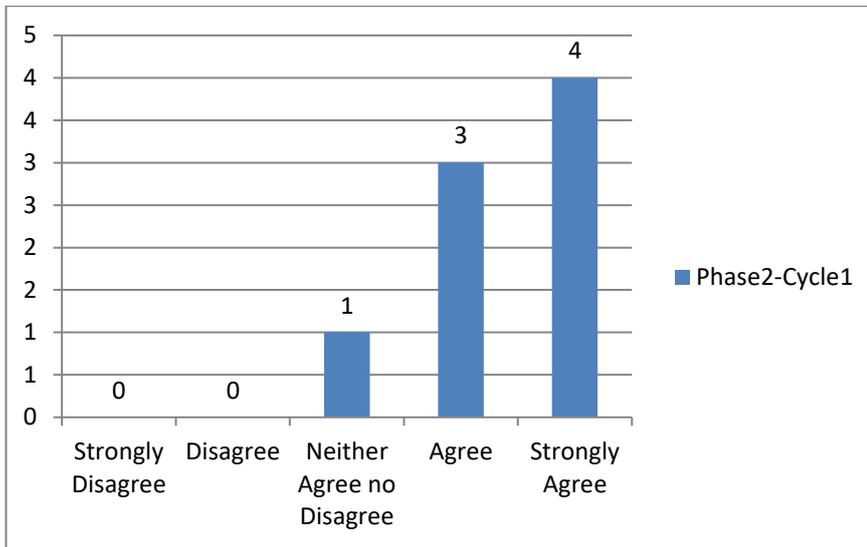


Figure 27: Phase2-Cycle1 - The e-learning software helped me to understand what computational thinking is.

There was a slight progressive drop in results as the students were asked whether:

- The e-learning software helped me to recognise computational thinking concepts. (refer to Figure 28)
- The e-learning software helped me to use computational thinking concepts. (refer to Figure 29)

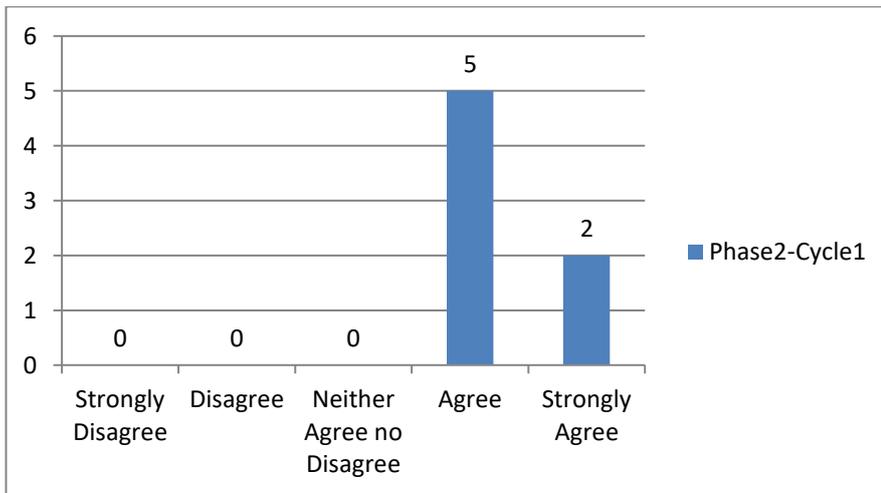


Figure 28: Phase2-Cycle1 - The e-learning software helped me to recognise computational thinking concepts.

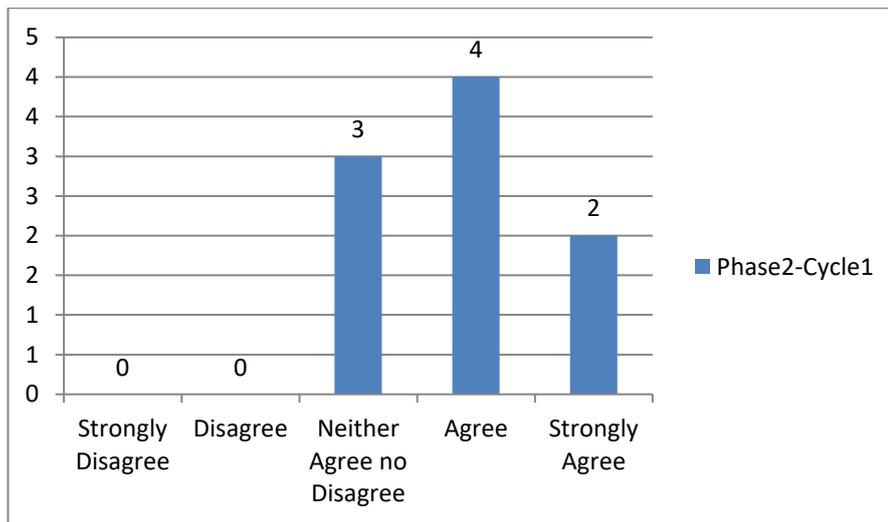


Figure 29: Phase2-Cycle1 - The e-learning software helped me to use computational thinking concepts.

The Phase2-Cycle1 survey instrument showed that as the learning became progressively more complex from recognising computational thinking to using computational thinking, the students became less confident.

In the focus groups, it was clarified that only one student had any prior knowledge of computational thinking. The students felt they had gained an understanding of what computational thinking is and had some confidence in recognising computational thinking, but when asked whether they felt confident enough to take a quiz, they expressed hesitancy. They explained that they knew that this was a research study and would not be tested, hence did not focus so keenly on learning.

*“I don’t remember much, but if I studied the E-Learning software properly it would be really easy to learn.”* [Student19]

*“The information was enough but need more opportunity to practice.”* [Student 25]

*“...with the information we have, you can review and practice and go back, I think we have enough.”* [Student 23]

Building on the results from the survey (Figure 29), during the focus groups the students clarified that the e-learning software needed more practice activities related to computational thinking; in discussion it was understood that there are activities to understand and recognise computational thinking but no activities to use computational thinking concepts such as abstraction, decomposition and generalisation. This indicates that heuristic 6.2 was not implemented effectively in Phase2-Cycle1.

It was interesting to note that during the year-4 focus group, whilst discussing the word search activity, one student described how he approached the activity; his description was expressed in algorithmic and computational thinking concepts and terminology. When asked whether he did this intentionally he responded that *“I believe subconsciously yes, I wasn’t really thinking about it explicitly. But something before this slide puts you in the mood of computational thinking without you even realising it.”*

In Phase 2-Cycle 1, the results relating to “*Support Problem Solving through Computational Thinking*” were moderately positive. However, the e-learning software needed more practice activities related to using computational thinking concepts such as abstraction, decomposition and generalisation. In Phase2-Cycle2, further investigation could not be progressed since the e-learning software in this cycle only covered approximately 40% of the material covered in Phase2-Cycle1. This meant there was less scope to include more activities to use computational thinking concepts.

## B.5 Learning Object Ranking

With reference to Table 3, in Phase 1 and Phase2-Cycle1, the students were asked to rank the educational benefits (1 is the most beneficial and 10 least beneficial) of the different Learning Object types. Ranking information was not collected in Phase2-Cycle2 since all Phase 2 participants had responded in Phase2-Cycle1.

This ranking between the two phases was significantly different, with some notable surprises, such as Video dropping from 1<sup>st</sup> place to 7<sup>th</sup> place, quizzes jumping from 7<sup>th</sup> place to 3<sup>rd</sup> place and games dropping from 3<sup>rd</sup> place to 6<sup>th</sup> place. These rankings will be discussed further in the relevant sections.

Phase 1		Phase2-Cycle1	
Learning Object	Rank	Rank	Learning Object
Video	1	1	Pictures / Photos / Diagrams
Problem Solving	2	1	Animations / Simulations
Games	3	3 <sup>1</sup>	Quizzes
Pictures / Photos / Diagrams	3	4	Problem Solving
Animations / Simulations	3	5	Text
Assessments	6 <sup>2</sup>	6	Games
Quizzes	7	7	Video
Audio	8	8	Collaborative Activities
Text	9	9	Assessments
Collaborative Activities	10	10	Audio

Table 3: Phase 1 and Phase2-Cycle1 - Learning Object Rankings

<sup>1</sup> Instead of ranking 2<sup>nd</sup> a ranking of 3<sup>rd</sup> better reflects the fact that 2 Learning Objects were ranked higher.

<sup>2</sup> Instead of ranking 4<sup>th</sup> a ranking of 6<sup>th</sup> better reflects the fact that 5 Learning Objects were ranked higher.

## B.6 Video

In keeping with the 1<sup>st</sup> ranking in the questionnaire, the students confirmed quite strongly in the Phase 1 focus group discussion that the kind of video shown on screen 3 gives learning benefits.

The drop to 7<sup>th</sup> place in Phase2-Cycle1 is inconsistent with the other feedback received in the survey instrument and the focus groups. There were some comments about the video quality:

*"Some videos were of low quality and were difficult to understand what was written on the screen."*

[Student14]

During the year-5 focus group, it was clarified that this comment was only in relation to the video tutorial for programate and that in fact the educational value of the videos was confirmed by the students.

In the survey, one student commented that:

*"I like the fact that there are many videos and animations throughout the software which help us understand and comprehend all the information with ease."* [Student 23]

In the year-4 focus group, the students commented that:

*"...most were 2-3 minutes long, short and on point"* [Student 19]

*"keeps your attention... I think it's really helpful to have audio, video and these things to improve the learning experience."* [Student 23]

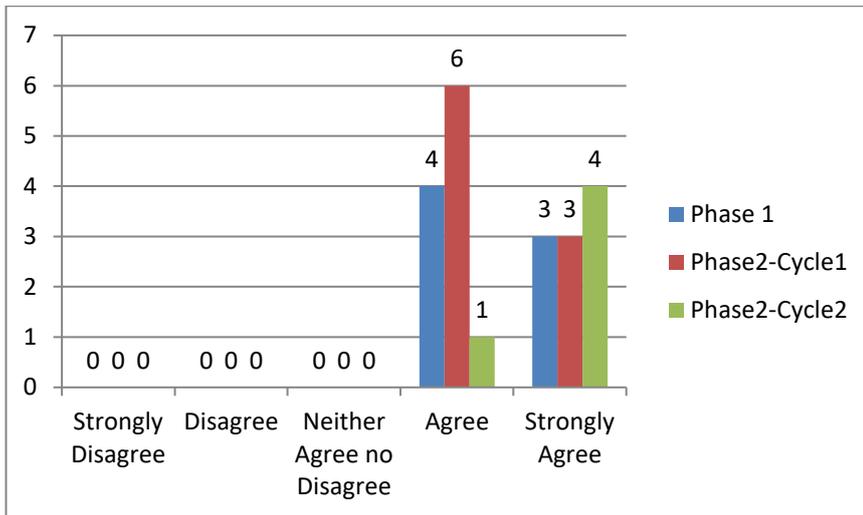
In spite of the drop in ranking, and in consideration of other survey instrument findings and focus group findings; videos remain a valuable tool in support of visual modal preference (heuristic 16.1), and visualisation approaches remain important within the pedagogy.

## B.7 Activities

Coming broadly under the umbrella of activities, we look at problem-solving, practice activities, quizzes, games, and simulations. With reference to Figure 30, in both Phase 1 and 2, the students either agreed or strongly agreed that the activity-based (interactive) components of the e-learning software provide support for understanding the subject matter.

In the Phase 1 questionnaire and focus group results, the students showed a preference towards active learning activities. During the focus group, the preference was expressed for more activities (games) such as the jigsaw puzzle and challenges / questions that make you think.

In the questionnaire, one student commented that *"I mostly like the interactivity of the software and the fact that I am able to solve examples closely linked to real life situations."* [Student 5]



**Figure 30: Phase 1 and 2 - The activity-based (interactive) components of the e-learning software provide support for understanding the subject matter.**

In Phase2-Cycle1, based on the open question survey responses the feedback was broadly positive:

*“It is much better as it is interactive, it has some bugs though”* [Student 16]

*“Games/Interactive components are really engaging. Videos and animations are an effective way of learning something. Sense of accomplishment when you find the correct answer is satisfying”* [Student 14]

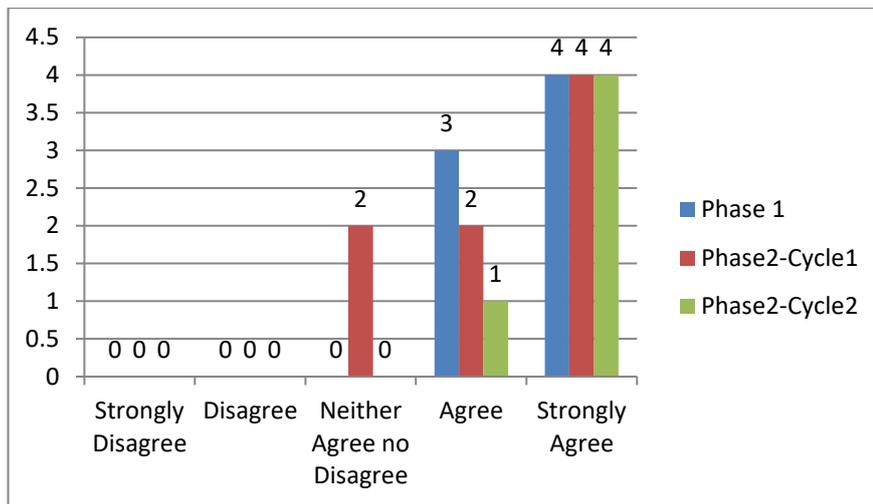
*“A positive is variety of content & activities”* [Student 13]

However, not all feedback was positive:

*“I disliked some of the activities as some of them became repetitive and sometimes annoying to complete what felt like the same activity over and over again.”* [Student 23]

The above point primarily reflected that some of the students felt the drag and drop functionality in some of the activities was a bit finicky, which in turn caused frustration.

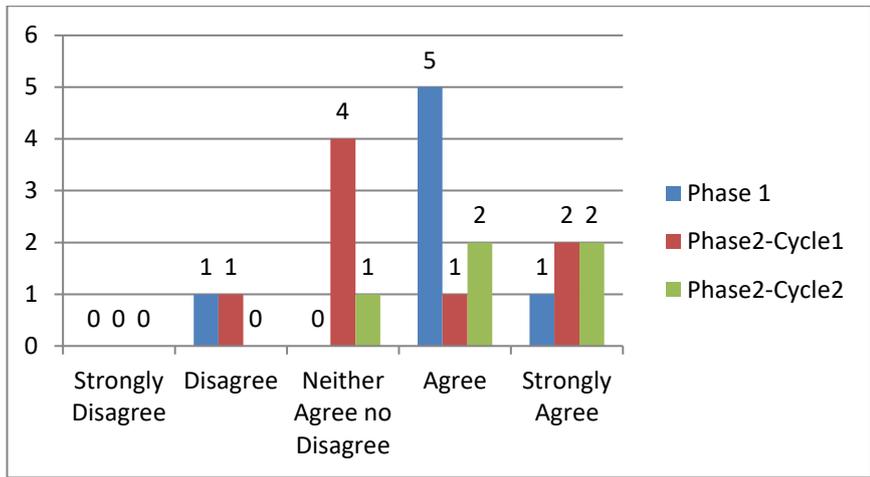
During the Phase 1 focus group, the students confirmed their preference to work through problems and confirmed that the activities in the e-learning software were more problem-solving based and not the kind of questions that focus on recounting from memory. With reference to Figure 31, this is reaffirmed in their questionnaire responses across all three measurements.



**Figure 31: Phase 1 and 2 - The assessment activities in the e-learning software encouraged me to think in order to build my answers.**

It is less desirable that three students agreed, and two students strongly agreed with the statement “*The assessment (quiz) activities in the E-Learning software encouraged me to recall previous knowledge to answer the questions.*” This is less desirable since as part of active learning the instructional design should **not** focus on memory recall, but more on thinking through problems. However, to some extent, this was understandable in the context of Phase2-Cycle2, since Level 1 of the e-learning software has a significant focus on theory, and Levels 3 and 4 which will be represented in Phase 3 have a much stronger focus on active learning.

With reference to Figure 32, it is important to note that in Phase 1 the majority of students either agreed or strongly agreed that the learning content in the e-learning software prepared them for the assessment activities. In contrast, in Phase2-Cycle1 only three from eight students felt that the learning content prepared them for the assessment activities. This result is unexpected since a significant portion of the learning material and the assessment activities remain unchanged between the two phases. One potential explanation for this result is that the students missed the learning material; this is postulated due to the previously reported feedback on-screen instructions and within-screen navigation (refer to section B.1.5). A second potential explanation is that some of the students did not like the additional open questions added to the e-learning software. These questions were more reflective in nature but were misinterpreted to be based on memory recall. During the focus group discussions, there was a split opinion between the students, some preferred to have these questions changed to closed type questions, but others appreciated the prompt to reflect and think. In Phase2-Cycle2, the student response reverted to more positive feedback with four from five students either agreeing or strongly agreeing that the e-learning software prepared them for the assessment activities.



**Figure 32: Phase 1 and 2 - The learning content in the e-learning software prepared me for the assessment activities.**

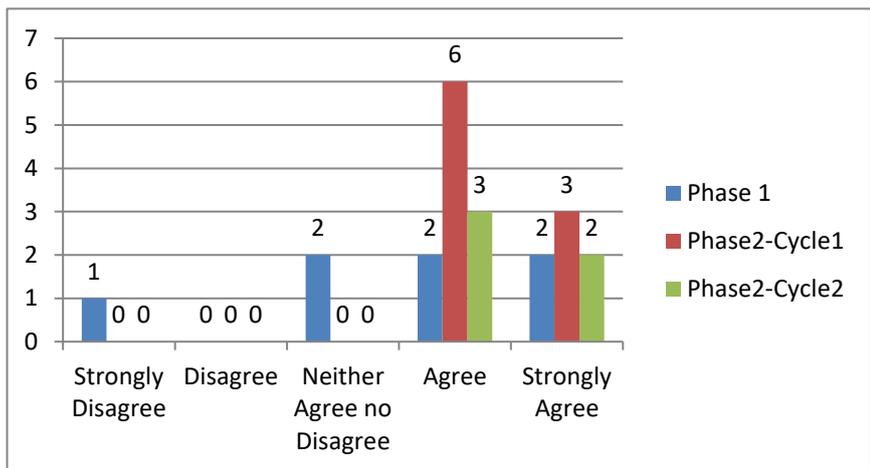
The Phase2-Cycle2 result was further confirmed by the students’ open comments from the survey:

*“There was a build-up of knowledge towards quizzes, which gave you the proper knowledge and you had to focus on that to complete the quizzes.”* [Student19]

*“In order to answer the quiz questions, I had to go back to the material in order to find the answers, and it encouraged me to revise the material and learn it better.”* [Student14]

*“The assessments summarized the content and connected different parts to each other, therefore making it more interesting as I needed to be more creative.”* [Student18]

With reference to Figure 33, an area for improvement over Phase 1, was that there were mixed results with regards the students’ level of engagement with the interactive activities. These results were then improved in both cycles of Phase 2 with all students agreeing or strongly agreeing that *“the activity-based (interactive) components of the E-Learning software are engaging.”*

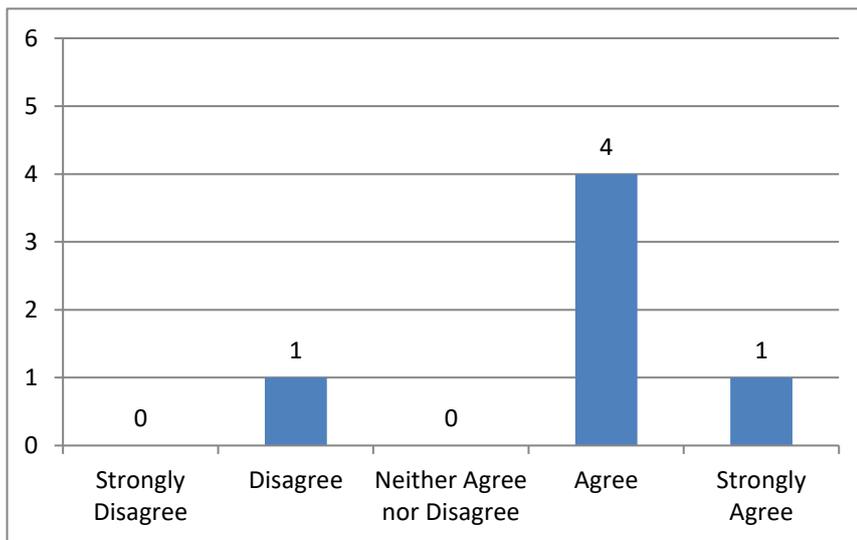


**Figure 33: Phase 1 and 2 - The activity-based (interactive) components of the e-learning software are engaging.**

## B.8 Text

The investigation of text material was carried out in Phase 1 and both cycles of Phase 2. As discussed in section B.2, in Phase 1, it is acknowledged that the e-learning software had a heavy text bias. The students clearly reacted with comments in the survey instrument open questions and in the focus group; additionally, they ranked text 9<sup>th</sup> out of the 10 Learning Object types.

However, with reference to the questionnaire results reflected in Figure 34, the students understand the need and value of text; five from six students either agree or strongly agree that the text material provided support for understanding the subject matter.



**Figure 34: Phase 1 - The text material of the e-learning software provides support for understanding the subject matter.**

In the questionnaire and in the focus group the students expressed the opinion that the e-learning software should have text, but not be so text focused. They expressed the opinion that the text should not be removed and suggested to instead: break up the text, reduce font size, avoid big blocks of text and try to include more visual elements and videos. This latter point aligns with the multi-modal approach recommended in the pedagogy.

The strong student response in Phase 1 resulted in updates to both the pedagogy and the e-learning software. Based on these changes, in Phase2-Cycle1, the text ranking jumped from 9<sup>th</sup> place in Phase 1 to 5<sup>th</sup> place, and only one student mentioned the amount of text in a negative context:

*“too much text that makes it boring at some points and not always on point”* [Student 17]

The follow-up discussion on this point in the Phase2-Cycle1 focus groups led to mixed responses:

*“the amount of text is good enough, you have to learn, there can’t be just bullet points there has to be a paragraph or something.”* [Student 25]

*“some slides were still a little heavy with text. Maybe you can split those over more slides. If possible”* [Student 19]

*“it is an improvement over the previous version.”* [Student 14]

*“...the text was also decent,”* [Student 19]

In both Phase2-Cycle1 focus groups, the students who mentioned there were still some screens with too much text were asked to provide an example, and the facilitator flicked through the screens to jog their memory. In both focus groups, the students could not pick an example in which they felt there was too much text. To support the discussion, the facilitator went to screen 9, which focuses on computational thinking concepts and approaches; this screen has the heaviest text content of the software. In the year-5 focus group, there was some debate, but eventually, the group reached a consensus that the text content was necessary and there would be no value in splitting the 11 concepts and approaches into separate slides.

In both focus groups, the conclusion was, overall the level of text is fine, but there might be one or two screens where the text content is a little heavy.

In the focus groups, it was also clarified that the approach of sparingly using colour text, bullet points, rollover text and chunking text into small paragraphs was well received by students; this is aligned with Phase 2-Cycle1 heuristic 22.1 guideline-2. However, a concern was identified regards the use of rollover text; many students interpreted this to be optional learning material. Hence key educational material should not be presented in this manner, this is aligned with heuristic 22.1 guideline-4.

Despite the initial concerns on the amount of text in the e-learning software, and with reference to Table 4, the trend across Phase 1 and 2 shows the students recognise the value of the text in supporting their understanding.

		Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Phase 1	N=6	0	1	0	4	1
Phase2-Cycle1	N=9	0	0	0	8	1
Phase2-Cycle2	N=5	0	0	0	3	2

**Table 4: Phase 1 and 2 - The text material of the e-learning software provides support for understanding the subject matter**

The importance of text within a balanced modal delivery is aptly described by one student in the year-4 focus group (Phase2-Cycle1):

*“Lots and lots of text on a screen and you start to lose attention; audio and video helps you to clear your mind and small bites of text really helps.”* [Student 23]

After the intervention in Phase2-Cycle1, there were no further negative comments in relation to text content.

## B.9 Visuals

With reference to Table 3, the importance to students of visual elements (such as symbols, logos, diagrams, pictures, illustrations etc.) is clearly shown. In Phase 1, they were ranked a joint 3<sup>rd</sup> from 10 learning object types, and move to joint 1<sup>st</sup> rank in Phase2-Cycle1.

During the Phase 1 focus group, when asked how the e-learning software could be made more interesting and eye-catching, the students suggested more pictures and diagrams, and less focus on text. However, they were clear that they were not interested in visual elements and fancy animations just for aesthetic appeal. The student responses are aligned with heuristic 17 that suggests text material should be supplemented with graphical elements that have educational value.

With reference to Figure 35, the students give a positive response in both phases that the visual elements were meaningful.

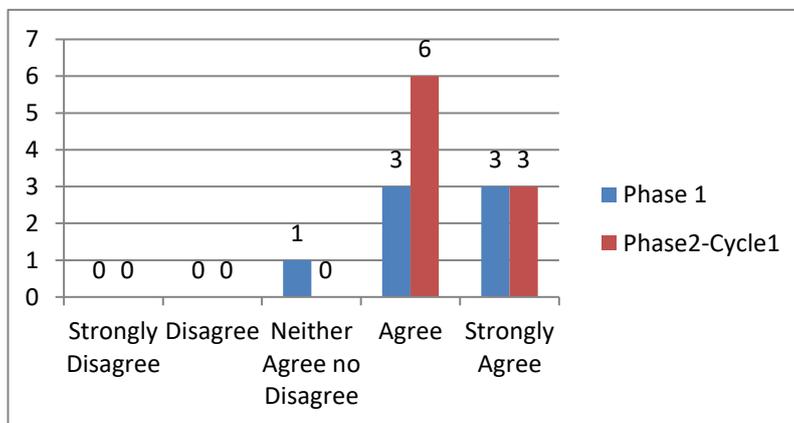


Figure 35: Phase 1 and Phase2-Cycle1 - The visual elements (symbols, logos, diagrams, pictures and illustrations etc.) of the e-learning software are meaningful.

However, with reference to Figure 36, the students gave a comparatively lower response regards whether the graphical elements were appealing as compared to whether they were educationally meaningful. In the Phase 1 questionnaire, one student commented that *“The thing that I dislike is that it's not very colourful.”*

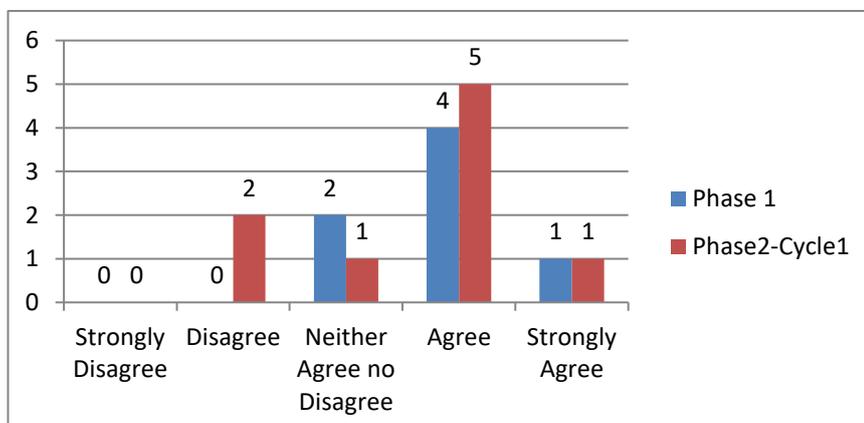


Figure 36: Phase 1 and Phase2-Cycle1 - The visual elements (symbols, logos, diagrams, pictures and illustrations etc.) of the e-learning software are appealing.

In Phase2-Cycle1, one year-4 student responded in the survey:

*“The overall design of the software needs a bit of an upgrade not the most appealing software I’ve used.”* [Student 25]

When asked to comment in the focus group, two of the year-4 students advised

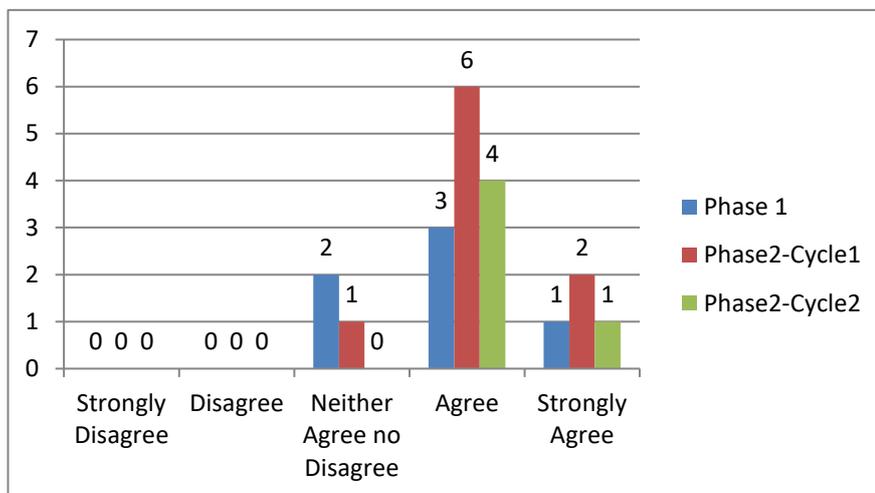
*“exercises were good, did not like the design of the interface..... colours where a bit dull were not bright”* [Student 25]

*“could be more user friendly - better graphics”* [Student 19]

However, upon further discussion with the facilitator the difference between usability and the aesthetics of interface where clarified. At this point, one student advised it was the way it looked, and all three students nodded that the focus was not usability, but on the way it looked, i.e. design aesthetics.

Carrying through even into Phase2-Cycle2, there remained one comment that the aesthetics of the e-learning software could be improved.

With reference to Figure 37, there was positive feedback in terms of motivation across Phase 1 and both cycles in Phase 2. With the exception of a few responses in Phase 1 and Phase2-Cycle1 who were indifferent, the students either agreed or strongly agreed that the visual components of the e-learning software were engaging.



**Figure 37: Phase 1 and Phase 2 - The visual components of the e-learning software are engaging.**

During the Phase2-Cycle1 focus group, two students commented that

*“Personally, I think that visualising is very important.”* [Student 23]

*“I really liked the short videos; I think the pictures were actually really good, the text was also decent...”* [Student 19]

Most importantly, with reference to heuristics 16, 17 and 17.1 and the educational value of the visual elements; seven from nine students felt the visual material helped them understand the subject matter,

and in Phase2-Cycle2 all students felt the visual material helped them understand the subject matter (refer to Figure 38).

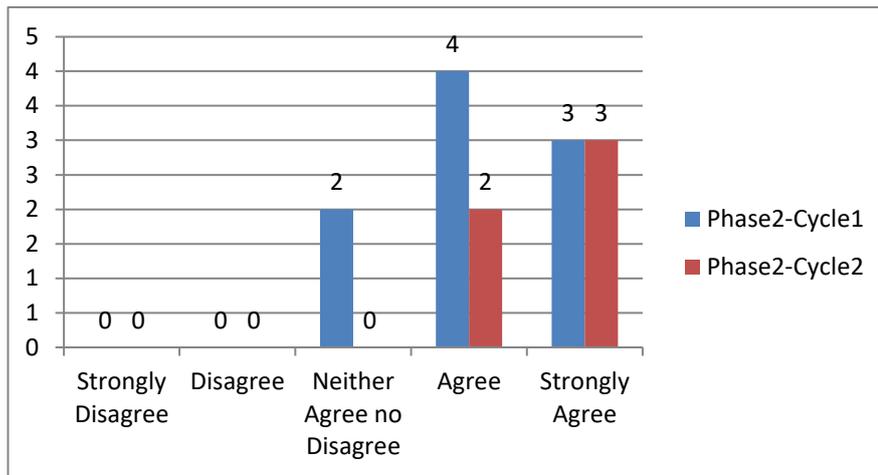


Figure 38: Phase 2 - The visual material in the e-learning software helped me understand the subject matter.

Overall, the findings from Phase 1 and 2 are well aligned with the e-learning pedagogy, which focuses on meaningful and engaging visual elements that support learning, with less focus on the aesthetic appeal of the visual elements.

## B.10 Audio

In both phases, the audio material has consistently been ranked low; in Phase 1, it was ranked 8<sup>th</sup> from 10 learning object types, and in Phase2-Cycle1, it was ranked last. This is further supported by Figure 39, which shows the students' continued mixed response across both phases, on whether audio material provides support for their understanding of the subject matter.

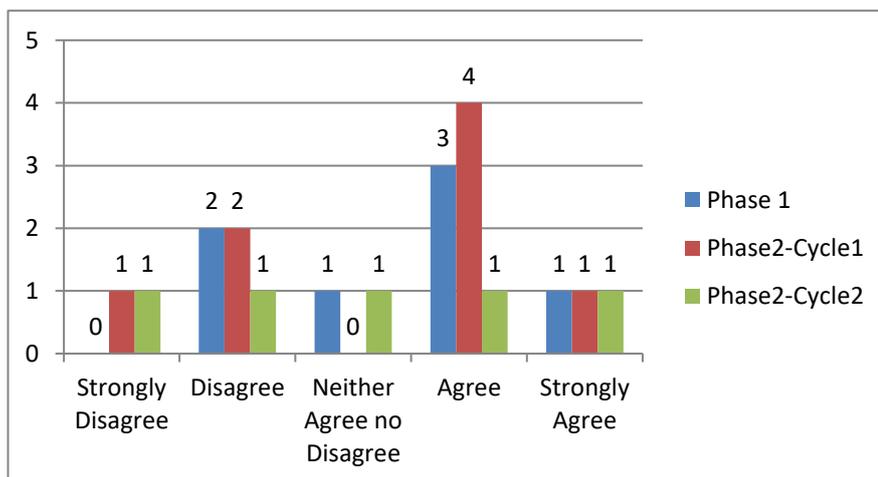


Figure 39: Phase 1 and 2 - The audio material of the e-learning software provides support for understanding the subject matter.

During the Phase 1 focus group, the students gave the consensus that the audio should remain for learning material, but with an option to turn it off and that the audio quality needs to be improved to avoid hiss,

background noise and minor mistakes. As a final point, the students confirmed that instructions should not have audio.

The student response in **Phase 1** resulted in updates to both the pedagogy and the e-learning software. The software was updated with a mute button, and the e-learning pedagogy was updated to reflect that e-learning software should give support to either enable / disable audio and must remain pedagogically effective even when audio is disabled.

The **Phase2-Cycle1** focus groups, provided a wider context in which to view these mixed results. The students confirmed that the concern of poor audio quality was no longer a problem. Discussions within both focus groups were split between those who saw educational value in the audio and therefore used it and those who didn't. However, since there was now a mute button, the consensus remained that the audio should remain in place unchanged.

The results in **Phase2-Cycle2** were consistent with the findings of Phase 1 and Phase2-Cycle1. The audio material was viewed as a lower priority, but the optional narration is a welcome extra that should be kept.

## **B.11 Collaboration**

The investigation of collaborative learning was carried out in Phase 1 and Phase2-Cycle1. With reference to Table 3, collaborative learning (heuristics 11, 11.1 and strongly related to heuristics 9 and 12) has shown a small improvement in Phase 2-Cycle 1, moving from 10<sup>th</sup> to 8<sup>th</sup> place.

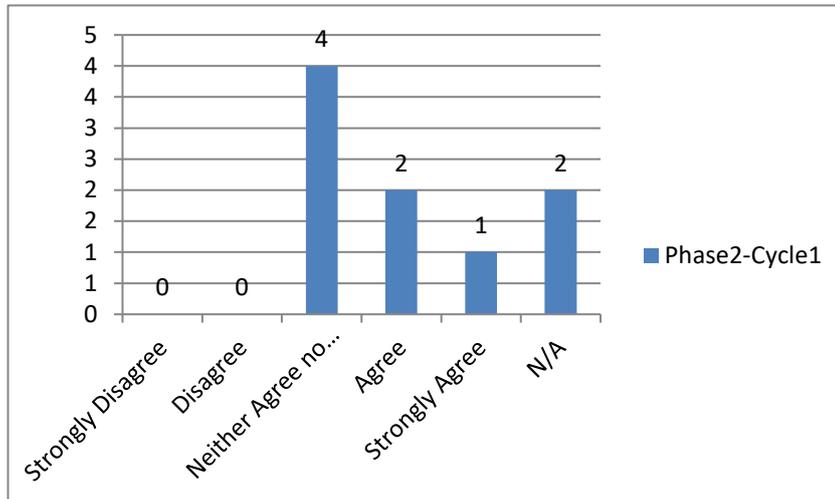
The Phase1 ranking result was confirmed by the results of the observation study and the focus group discussion. During the focus group, it was clear that the students understood at a conceptual level the reasons and value of collaborative activities, but did not activate them in practice. In the discussion forum activity, the students all made their comments in the forum, but none of them built on, commented on, or debated their fellow students' responses. Likewise, in the focus group, the students acknowledged that none of them attempted the pair-work instant messaging activity.

In Phase 1, the underlying reason for these disappointing results was unclear, but postulated to be related to the following factors:

1. A need for further in-depth training and instructions on collaborative activities, this implies a greater emphasis on heuristic 11.
2. The experiment design offers an unrealistic setting for collaborative learning. Typically, collaborative learning is performed across a longer period in which the student has weeks / months to review, respond and interact. In this experiment, the students were constrained by a very tight experiment schedule.

In response to the Phase 1 results and point 1 above, the e-learning pedagogy was updated with significant guidelines on how to create a learning community in which students can become invested in working collaboratively. Unfortunately, regards point2, in Phase2-Cycle1 little could be done to change the experiment design to offer a more realistic setting for collaborative learning.

The disappointing results continued in Phase2-Cycle1; the low ranking of collaborative learning was reaffirmed by the poor results reflected in Figure 40, showing that only three from eight students agreed or strongly agreed that collaborative activities helped them understand the subject matter. Furthermore, an analysis of the Collaborative Learning Environment showed that many of the students did not attempt the collaborative activities.



**Figure 40: Phase2-Cycle1 - The collaborative activities (group or pair work) helped me understand the subject matter.**

These findings are aligned with the feedback from Phase 1; but in Phase2-Cycle1, a clearer explanation of these findings was possible.

As part of the survey, the students responded to the following question - Describe briefly, whether the collaborative activities gave you any learning or motivational benefits and what those benefits were. The student responses showed they had a very good grasp of the value and benefits of collaborative learning.

*"The collaborative activities helped me learn a lot as I heard about other people's opinions on the subject"* [Student 25]

*"Yes as my partner taught me things"* [Student 16]

*"The collaborative activities gave me and my partner the opportunity to help each other understand the questions we had. One could answer the questions of the other, which was really helpful in order to complete our task."* [Student 14]

*"The collaborative activities gave me motivation to work harder in order to not fall behind my partner."* [Student 18]

*"Encouraged me to better understand the material rather than simply glossing over me, because I had to explain it to my partner."* [Student 13]

*"I believe the collaborative exercises really help with learning as they were fun and interesting to participate in activities with classmates. They help us comprehend and understand information through a more fun interactive way."* [Student 23]

In the focus groups when discussing collaborative learning, the students expressed a positive attitude towards collaborative learning and its benefits. They expressed that they would like to have more collaborative activities: since other people can help you to understand; you can exchange ideas and opinions with others; it is really useful for homework; and that working with others motivates you and drives you to keep up with peers.

However, a critical factor that was expressed was:

*“it would be really useful for homework but not for in-class use.”* [Student 23]

The students acknowledge that collaborative learning is equally useful in class, but technology-enhanced collaborative activities are artificial in a classroom context and much more suited for homework, where you are not co-located with your fellow students. In the context of this study, the majority of time spent using the e-learning software and CLE was in class hence did not feel natural to the students. The students were reminded that they were asked to complete the e-learning from home, but this was misunderstood or forgotten by most students. The reality is that an optional research study is not a suitably attractive proposition for students to spend their free time on, much less to coordinate with others to jointly spend their free time on. However, the consensus from both Phase2-Cycle1 focus groups was that if collaborative learning and a collaborative learning environment were integrated into the normal learning process (including homework) that spans across the academic year, then they would have really liked to do it.

*“yes it’s much better than what we currently have to submit work from home.”* [Student 14]

What was tentatively postulated in Phase 1 was more clearly established in Phase2-Cycle 1, an experiment design to give feedback on collaborative learning would need to more naturally reflect the learning process across a longer duration in which the students have weeks/months to review, respond and interact. Unfortunately, in this study, this is not possible; each experiment was constrained by a very tight experiment schedule and most of this time was spent in class; this makes it more challenging and complex to establish trustworthy findings on collaborative learning.

During the Phase2-Cycle1 focus groups, a number of other interesting findings were noted. Initially, the year-4 students questioned the need to have a separate Collaborative Learning Environment (Google Apps for Education), suggesting that students could simply use their own personal social media accounts (i.e. Facebook, Skype, Viber, Yahoo, Gmail etc.). However, in discussion, they soon agreed that the logistics of coordinating communication for all students using their different personal accounts, and the associated security risk, create a significant challenge. The students understood that a uniform collaborative platform was needed. Year-5 students offered broad support for a uniform collaborative platform, and one student gave a very positive report of Google Apps for Education.

*“Google classroom is amazing feature on Google, which I think should be used everywhere. The forum type section was amazing; the google docs shared editing was amazing. The collaborative part has a lot of potential but it’s not quite there yet. But google docs and google classroom is perfect to use because*

*seeing other peoples responses and have the teacher comment on your answer and see what he has to say is perfect.” [Student 14]*

Both focus groups also showed an understanding of the benefits of a learning community that goes beyond school boundaries and that the benefits of such a community increase with the number of participants.

When discussing collaborative technologies, the students placed great value on forums, VOIP, screen sharing and shared editing (Google Docs), less value on chat facility and least value on video conferencing. However, the most important factor was not the technology, but the design of the activity must naturally engender collaborative work.

In relation to collaboration the abiding conclusions from Phase2-Cycle1 were:

1. Despite the mixed feedback, overall, the students saw good potential for collaborative learning.
2. There remains a learning curve for technology-enhanced collaborative learning since it is not the traditional way of working in a schools.
3. The research and experiment design were not conducive to evaluating collaborative learning, therefore, research findings cannot be taken at immediate face value; they required a more complex and in depth analysis and interpretation.

## **B.12 Authentic Learning vs Avoiding Overload**

In Phase2 cycle1 and cycle2, there was an investigation of the tension between authentic learning and avoiding overload. This was brought about because invariably high-school learning leads to some form of assessment or examination, and arguably, the current focus of the majority of schools is to prepare students for these assessments. However, there is also a school responsibility to develop well-rounded individuals, who can think beyond exams. This results in a pedagogical tension that is also reflected in the e-learning pedagogy, between heuristics:

- 1. Use authentic educational material, examples and activities.
- 18. Avoid adding learning content that does not directly support your instructional goal.

In accordance with heuristic 18, all learning material that does not directly contribute to examinable learning outcomes should be reduced or removed; this, in turn, weakens heuristic 1. This was discussed in both focus groups, and on balance, the students erred on the side of heuristic 1; they felt some of the additional learning material that is not directly examinable should be kept.

*“it might not be in the exam but it really broadens your perspective, especially in giving you examples of real-life applications I think it really helps to have this backup in the back of your mind to be able to compare something when you have an exercise that might not be the exact thing on the screen but this could help you to find an answer.” [Student 23]*

*“but after a few slides of really straight to the point information, it really helps to give you a different look change – it stops the whole learning experience from seeming like a chore.” [Student 23]*

The important factor was that each student needed to use their judgement to decide whether they would focus on such learning content. It was agreed that in order to support in this decision-making process such learning material would be clearly marked with a visual marker (icon) to reflect that it is additional / supplementary information.

In Phase2-Cycle2, this was implemented using a green “i” icon that was animated to notify students that this material was additional information, that would not be examinable.

During the Phase2-Cycle2 focus group, the students reasserted the point that it is *“always a good idea to have more information to have students understand more effectively”* [Student 19]. However, the students did not clearly state that the icon had the desired effect; instead, they advised that:

*“mmh (yes) basically if you know what each symbol means then the rest is...(clear).” [Student14]*

*“If they don’t know the symbol then they might think the opposite that it is necessary for them to read.” [Student18]*

The above feedback makes it even more important that the students review the pre-training which outlines what all the symbols and buttons mean. In addition, the green “i” was changed to a red “i” to reflect better that this information is non-essential and the students’ may consider not reviewing it.

### **B.13 Virtual Manipulation Environment**

The e-learning pedagogy promotes active engagement and mindful activity; in particular, multiple heuristics (Heuristics 4, 6.2 and 13) advocate the use of a virtual problem manipulation environment to support mindful activity. In Phase 1, the progranimate environment was introduced, and in Phase 2-Cycle 1 the pencilcode turtle environment was also introduced.

Progranimate was originally selected since it bridges the gap between flowcharts and pseudocode; allowing the students to create and execute a flowchart that visually steps through the underlying pseudocode. This functionality is very powerful in a learning context, but Progranimate has some drawbacks that became apparent in Phase2-Cycle1. Progranimate is not a true cloud application, it is based on a JAR applet that requires Java to be installed, enabled and a specific security exception activated for the JAR file. This additional setup activity was frustrating and unpopular with students. Also it was often overlooked meaning the application failed to execute. Additionally, as an application, the students felt it had poor usability.

*“it was more confusing than it’s worth. Usability was poor and overall a bit too time-consuming.” [Student 13]*

The facilitator acknowledged that there is a learning curve to set up and use progranimate and asked whether the students felt this would be offset if the application was used in the course of their normal learning throughout the year. The response from one student clearly refuted this assertion:

“...that in normal usage we would get into more complicated problems so this tool would still not be very good since the tool is too time-consuming.” [Student 14]

Key criteria for a problem manipulation environment are that it should have a low floor in terms of ease of entry and a high ceiling in terms of features and functionality that learners can eventually master. Unfortunately, Progranimate did not meet this criterion and was replaced in Phase 2-Cycle2. The Google Draw app was used in Phase2-Cycle2 for flowcharting activities; this had the added benefit of supporting collaborative editing but does not map between flowcharts and pseudocode; additionally, it cannot be viewed as a true problem manipulation environment.

Pencilcode was introduced in Phase2-Cycle1 to support computational thinking and in particular to exemplify the “tinkering” approach, i.e. to engage the students with a playful activity. Although some of the students commented that the design of the activity was not the most engaging; almost all students expressed a positive opinion of the pencilcode environment.

## B.14 Connectivism and the Web

The investigation of connectivism and the web was carried out in Phase 1 and Phase 2-Cycle1. With reference to Figure 41, the students are aware of the value of using the Web to support their subject learning. However, during the Phase 1 focus group it became clearer that the students were not using the web as much as would be anticipated.

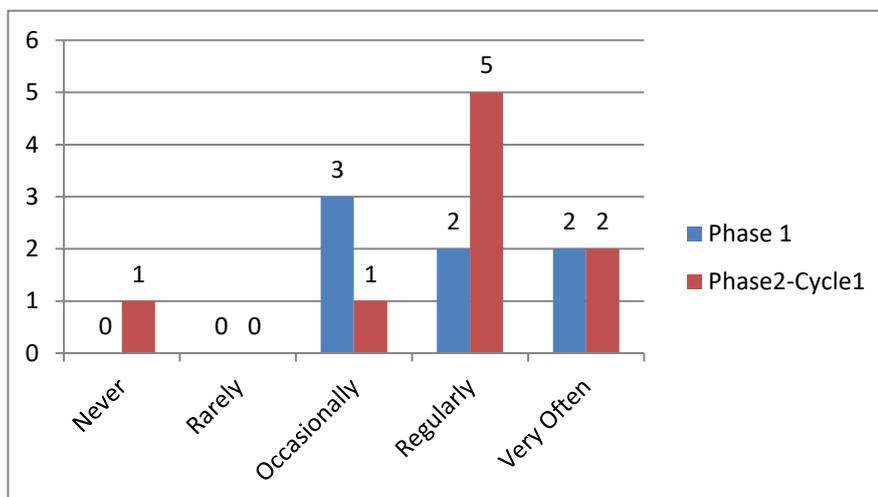
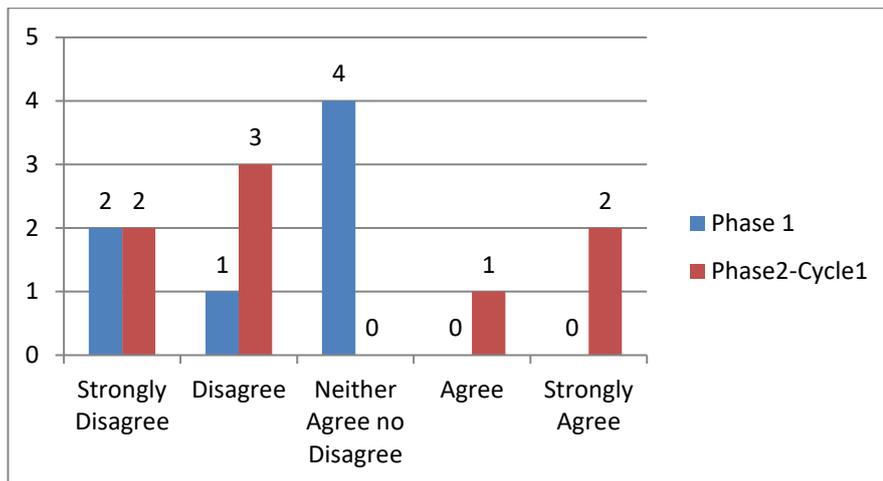


Figure 41: Phase 1 and Phase2-Cycle1 Summary: I already use the Internet and the Web to support my learning of the computing subject.

In relation to their subject learning, student Web usage falls into two broad categories; to better understand the material in which they do not feel confident of in the classroom learning, and to investigate new learning topics.

During the focus groups, the students showed an understanding that a critical appraisal of the information found on the web is necessary since the source and quality of information may be unreliable.



**Figure 42: Phase 1 and Phase2-Cycle1 - I would prefer using the Internet and the Web to support my learning of the computing subject, rather than this e-learning software.**

With reference to Figure 42, the students showed a weak preference towards the e-learning software compared to using the Web for their subject learning. This preference was reiterated during the Phase 1 focus group session. Additionally, the responses to the open question and the focus group discussion showed a rational and perceptive evaluation of the advantages and disadvantages of using the e-learning software as compared to using the Web; student feedback from the questionnaire included:

*“I believe the E-learned software has everything I need, hence not requiring any other information that I must know to be obtained by the internet.”* [Student 4]

*“Through the use of an E-Learning software, I can use the Web as well, where the links to videos and blogs will be included in the software.”* [Student 2]

*“I don't mind using both of them, because each one of them gives me information that I need.”* [Student 8]

*“Often on the Internet, details are mostly vague and one does not fully understand what he/she was looking to learn.”* [Student 5]

*“They are different things. on the internet you can get easily immediately the information you want and learn what you want. and in the E-Learning software IF you find what you want there is detailed reliable information.”* [Student 6]

*“Both have their uses. This software offers a guided approach, while I can research anything using the Web, without a particular order. Therefore, using both at the same time would be the best approach in my opinion.”* [Student1]

Following on from the above feedback and reiterated in the Phase 1 focus group was that the students perceived the e-learning software to be comprehensive in its content and that they preferred the structure of having one place to learn from avoiding the wasted time in searching the web and evaluating whether the information they find is correct. The web links included within the e-learning software were considered by one student to be *“extra and useful information about the matter.”* [Student 2]

This does not align with the connectivist standpoint that students want to be actively in control of what they learn, when and how, and that they do this by creating and cultivating a network of information nodes. However, it does align with the moderate connectivist approach suggested in heuristic 12 in which the e-learning software becomes the hub that suggests (links to) other learning resources that are known to be reliable.

The feedback in Phase2-Cycle1 was similar to that expressed in Phase1. With reference to Figure 41, the students were fully aware of the value of using the Web to support their subject learning. With reference to Figure 42, the students again showed a weak preference towards the e-learning software compared to using the Web for their subject learning; however, the feedback was more polarised between those who preferred the software and those who felt they have the critical thinking skills to evaluate content and prefer the flexibility of the Web. The responses to the survey instrument open questions reiterated the above findings more strongly:

*“because I feel more independent as a learner when I search the information I want to know on my own and I don't like the information to be brought by someone else” [Student 25]*

*“The internet: contains more information is easier to search through” [Student 13]*

*“you have all the information collected in one source and it is all checked and reliable when on the internet you might not find what you want.” [Student 17]*

*“It is easier to understand content from the software” [Student 16]*

*“The E-Learning software has activities and features that are much more engaging than looking up information on the Web. The Web sometimes contains sites with wrong information, so the E-Learning software would be a much more reliable and easy source of information.” [Student 14]*

*“The E-Learning software has everything in one place, so I don't need to search the whole internet for all of the different subjects separately, which helps me save quite a lot of time.” [Student 18]*

*“I would rather use this well designed and well planned out and worked on E-Learning software than trying to support my computing subject with scattered information on the web that sometimes might not even be true. Since the E-Learning software has all the valid information gathered into one course which is really helpful and easy to understand.” [Student 23]*

As in Phase 1, the e-learning software was perceived to be comprehensive, and the students preferred the structure of having one place to learn from, avoiding the wasted time in searching the Web and evaluating whether the information they find is correct.

This aligns with the moderate connectivist approach suggested in heuristic 12 in which the e-learning software becomes the hub that suggests (links to) other learning resources that are known to be reliable.

## B.15 Recreating Books

The investigation into structuring learning material into book-like chapters was carried out in Phase2-Cycle1 and Phase2-Cycle2.

During the Phase2-Cycle1 focus groups, some unexpected feedback was expressed by the students. The e-learning software had an implicit structure and grouping of learning content that a number of students were clear on, but a significant portion of the students expressed the opinion that they would like explicit sections to be introduced. These sections would mimic a traditional chapter format, with the chapter learning objectives, learning material, review questions and finally a learning summary. When the facilitator expressed that we were aiming to avoid reinventing textbooks in e-learning; one student responded that:

*“We are used to the regular structure of learning through textbooks and it’s a bit bizarre, at least to me, to learn via E-Learning software... if E-Learning was structured more like a textbook but with interactivity and instant feedback of E-Learning software then I would prefer it. E-Learning software should try and build upon the current ways of learning.”* [Student 14]

When asked, the remaining students in the year-5 focus group expressed agreement with this sentiment. Furthermore, during the year-4 focus group a similar discussion took place in which the majority of students expressed that a structure similar to book chapters would be preferred.

The student response in Phase 1 resulted in updates to both the pedagogy and the e-learning software. The software was updated by breaking the learning material into levels with learning objectives, learning material and review questions. These levels were broken according to the colours of karate belts (refer to Figure 43); in Phase 2-Cycle 2, only the first two levels were implemented.

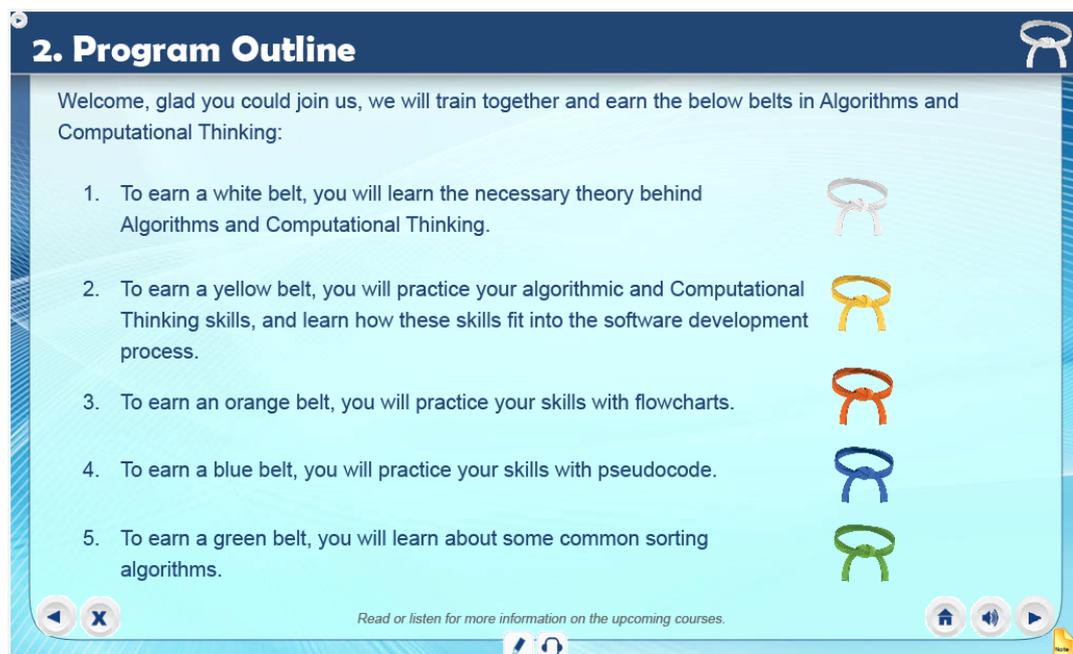
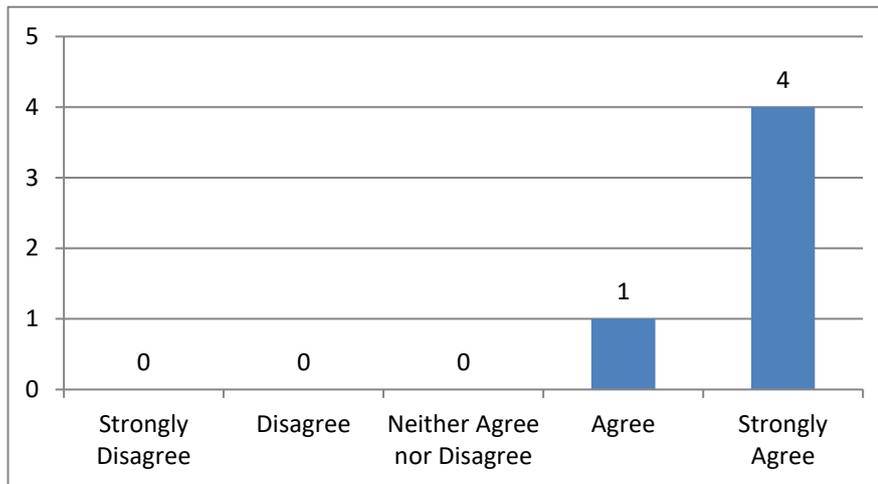


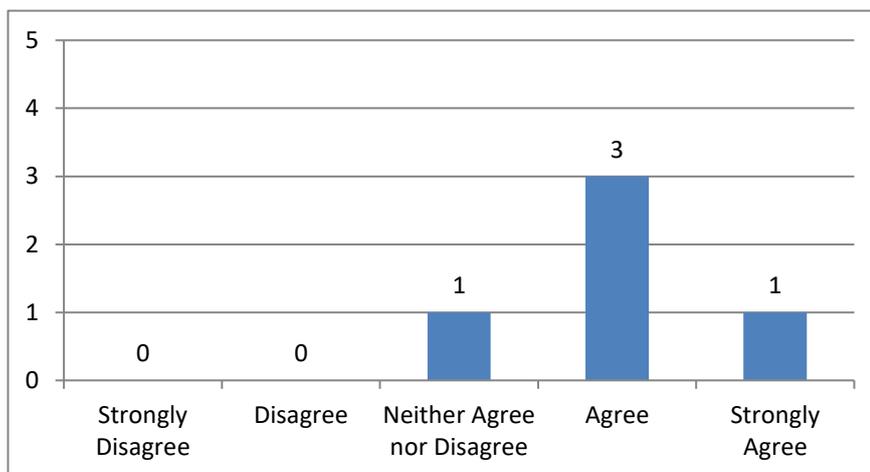
Figure 43: The five levels of e-learning Software.

The restructuring of the software into levels was received positively by the students. With reference to Figure 44, four from five students strongly agreed, and one student agreed with the statement *“The levels within the E-Learning software helped me to estimate my progress.”*



**Figure 44: Phase2-Cycle2 - The levels within the e-learning software helped me to estimate my progress.**

In addition, the students gave some indication that the levels provided some motivational influence to try to reach the next level. With reference to Figure 45, three from five students agreed, and one student strongly agreed with the statement *“The levels within the E-Learning software motivated me to want to progress to the next level.”*



**Figure 45: Phase2-Cycle2 - The levels within the e-learning software motivated me to want to progress to the next level.**

During the Phase 2-Cycle 2 focus group, one student summarised the student sentiment, to which the other students agreed.

*“Basically, it’s much easier when given in bite-size chunks, because once you finish one, you say to yourself I managed to learn this, so it will be easier to continue to the later one and it’s rewarding to see you have progressed through the different stages of learning.”* [Student14]

It was further suggested that at the end of the level, even if you have passed the level, the software should suggest areas of possible weakness where the student should consider further study.

## B.16 Motivation

The investigation of student motivation was carried out in Phase 1 and both cycles of Phase 2. Additionally, Gamification was introduced in Phase2-Cycle2.

Although it is quite a low benchmark comparison, in both Phase 1 and Phase2-Cycle1, almost all students felt it was more interesting to use the e-learning software to learn computing than the textbooks (refer to Figure 46).

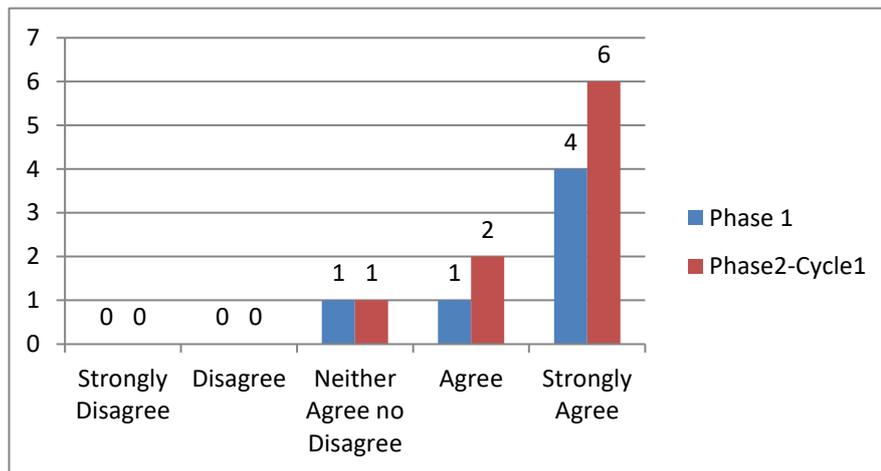


Figure 46: Phase 1 and Phase2-Cycle1 - It is more interesting to use the e-learning software to learn computing than the textbooks.

With reference to Figure 47, in both Phase 1 and Phase2-Cycle1, there is broad agreement that the students could use the e-learning software for independent study.

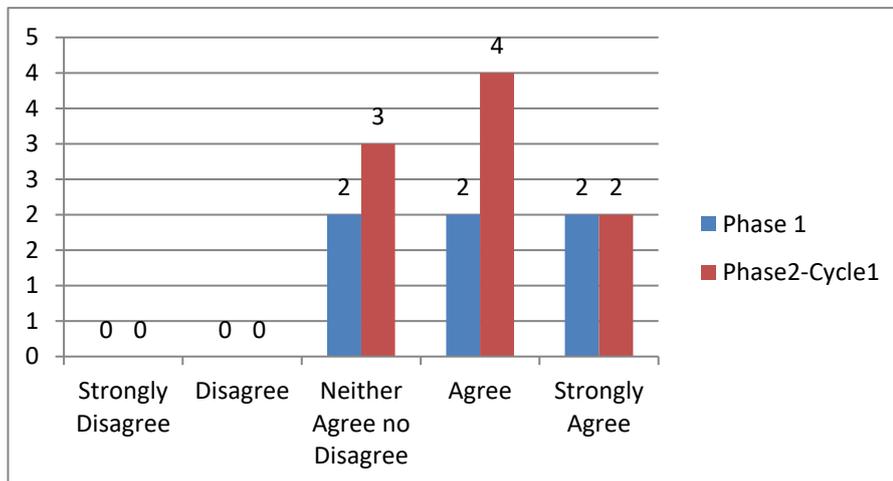
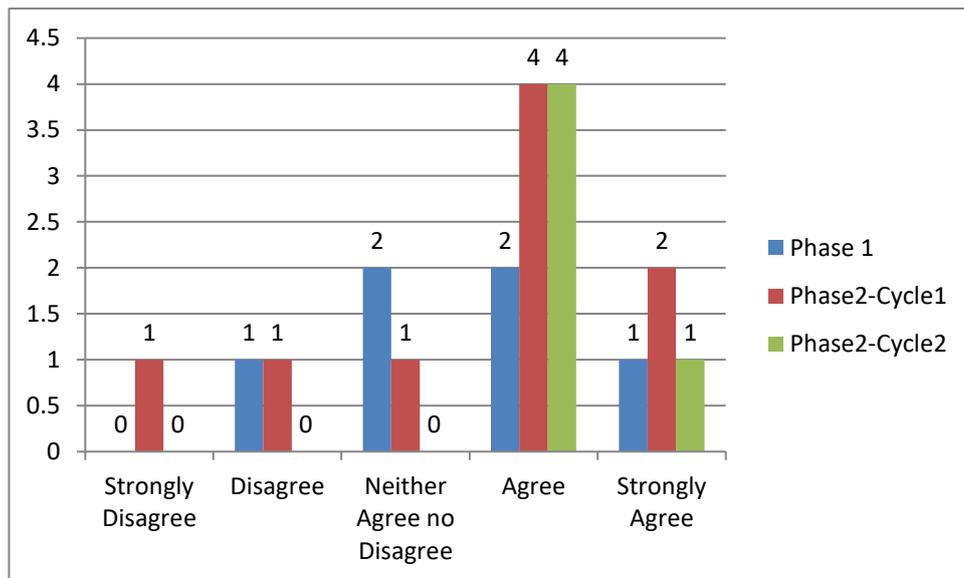


Figure 47: Phase 1 and Phase2-Cycle1 - I could use the e-learning software for independent study to learn Computing.

The investigation of students' enthusiasm and interest in computing was carried out in Phase 1 and both cycles of Phase 2. However, it should be noted that in Phase2-Cycle2 gamification was introduced, as was an increased focus on assessment performance.

With reference to Figure 48, in Phase 1, the e-learning software had mixed results in increasing the students' overall enthusiasm and interest in Computing. Although, during the Phase 1 focus group, five from six students agreed that the e-learning software sparked an interest in them towards the topic of algorithms. In Phase 2-Cycle1, the e-learning software had broadly positive results in increasing the students' overall enthusiasm and interest in computing. In Phase2-Cycle2, despite the mixed feedback related to gamification (Refer to section B.17), the student feedback regards the software's effect on their overall enthusiasm and interest in computing remained positive, with a slight improvement over Phase2-Cycle1.



**Figure 48: Phase 1 and Phase 2 - The e-learning software has increased my overall enthusiasm and interest in Computing.**

The investigation of student motivation using the IMMS instrument was carried out in Phase 1 and both cycles of Phase 2. According to Keller (1987), the major categories of the ARCS model are defined as:

1. **Attention:** Capturing the interest of learners; stimulating the curiosity to learn,
2. **Relevance:** Meeting the personal needs/goals of the learner to affect a positive attitude,
3. **Confidence:** Helping the learners believe / feel that they will succeed and control their success,
4. **Satisfaction:** Reinforcing accomplishment with rewards (internal and external)

The IMMS results across both phases are outlined in Figure 49 and are analysed in accordance with Keller's analysis protocol. These results range on a continuum between Moderately True (3) to Mostly True (4); the maximum on this scale is Very True (5). Across all three measurements, the results were broadly positive with room for improvement.

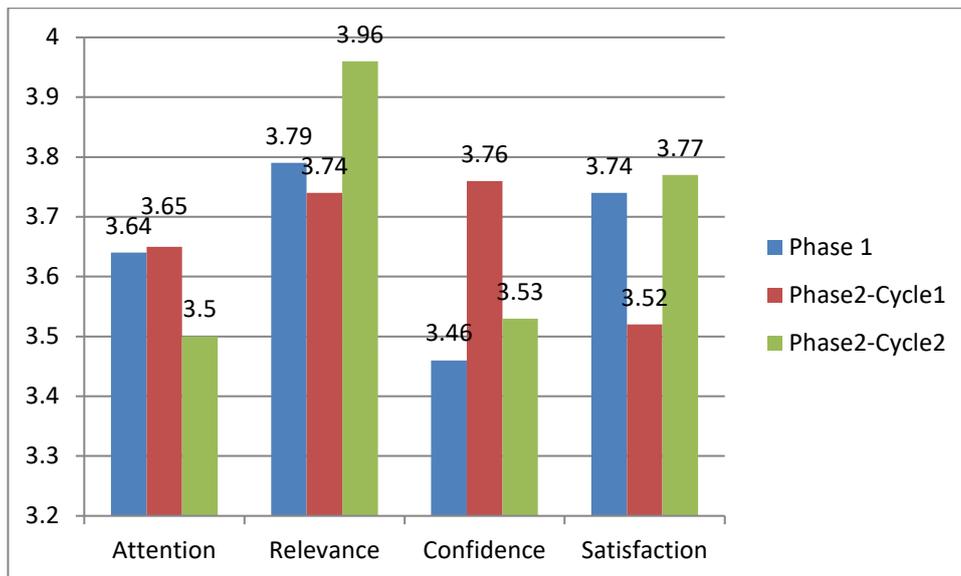


Figure 49: Phase 1 and Phase 2 - IMMS Motivation Survey Results.

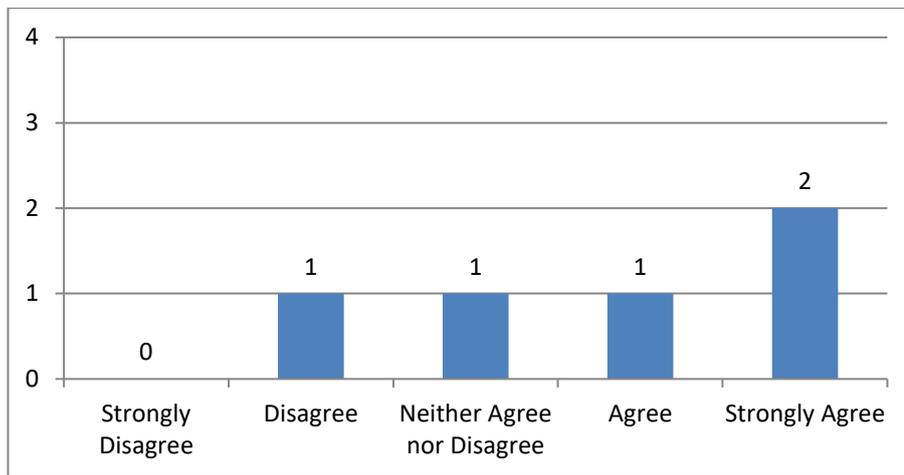
Whilst the sub-categories show some variation across the phases/cycles; there is consistency in the overall averages: in Phase 1 it was 3.65, in Phase2-Cycle1 it was 3.68, and in Phase2-Cycle2 it was 3.67.

In each version of the software, a concerted effort was made to use motivational approaches; Phase 2-Cycle1 focused on ARCS motivational design and Cycle 2 focused on gamification. Therefore, the stability in overall IMMS values could potentially be viewed as disappointing. However, this needs to be considered within the context that many of the aspects of the software were unchanged between versions and the student participants also remained the same; hence, some of the novelty and motivation value was lost. By Phase2-Cycle2, three students had used the software three times, and two students had used it twice.

We can postulate some tentative explanations of the sub-category results. It was unsurprising that the Attention result dropped by Phase2-Cycle2 since the students had become accustomed to the software. Likewise, Confidence would theoretically increase between phases/cycles; the drop in Phase2-Cycle2 can potentially be explained by the fact that the students were informed ahead of the experiment that there would be a focus on their assessment results from the software. Similarly, the increase in Satisfaction between Phase2-Cycle1 and Cycle 2 can be explained by the fact they had completed the software with new assessment questions that were more challenging.

## B.17 Gamification

Although the gamification heuristics were defined in Phase2-Cycle1, they were explicitly included in the Phase 2-Cycle 2 study scope. The intrinsic aspects of gamification defined in heuristic 15.1 were already inherently part of the e-learning software. What was included in Phase2-Cycle2 were the extrinsic motivational aspects defined in heuristic 15.2; specifically, these were support for levels, points, badges and a leaderboard. The findings related to levels were previously discussed in section B.15. With reference to Figure 50, the student response was weakly positive, from five respondents three agreed or strongly agreed with the statement *“The award of points and badges motivated me to work hard and progress.”*



**Figure 50: Phase2-Cycle2 - The award of points and badges motivated me to work hard and progress.**

During the focus group, the student feedback regards points and badges remained unenthusiastic. The student sentiment was aligned with the following comments:

*“I think in a real-life situation it wouldn’t be that..., or at least I don’t think it would affect me. I mean maybe if it was for someone of a younger age, maybe year 1, year 2, but for us I don’t think so.”*  
[Student14]

*“Maybe since we’re at an age that... maybe we won’t care enough about virtual badges and awards and stuff, I think that’s what he assumed. It won’t actually increase motivation for many of us, but maybe for some of people it will work. Maybe if it was altered in some way it could increase motivation maybe increase competition between the class to better perform.”* [Student 19]

One of the challenges was that the implementation of gamification elements was tied directly to the Learning Management Systems (LMS) which hosted the e-learning software. Support for gamification is not widespread or equal between LMS’ and would, therefore, be impacted by a school’s choice of LMS. In the context of Phase2-Cycle2, the LMS that was chosen was purported to offer native support for gamification elements, but unlike some other LMS’ it did not allow the ad-hoc definition of triggers for achievements and instead offered a limited set of award triggers based on completing a module, completing a module on time, completing a module early, completing skills which were associated to a module, skills advancement which was again linked to advanced modules. It should also be noted that the aforementioned LMS also had a number of deficiencies and bugs in standard LMS functionality, in particular, the tracking and reporting of SCORM quiz activities.

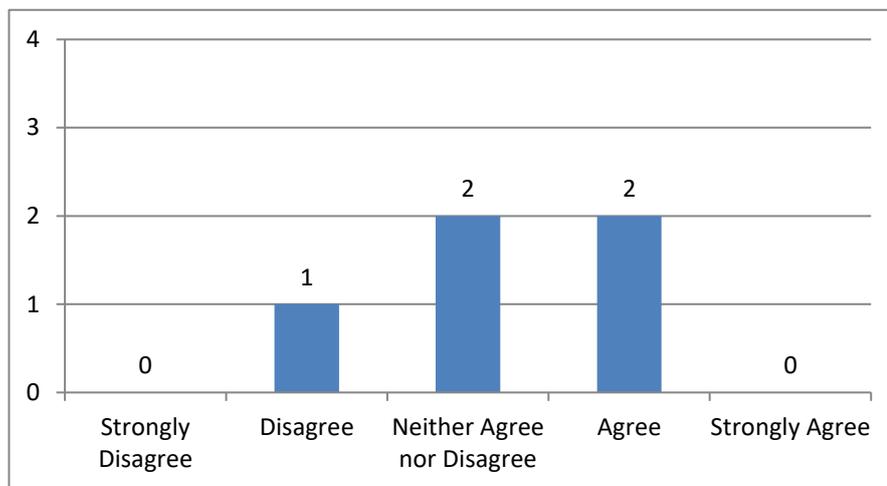
Overall, the level of granularity (module level) supported by the LMS was too high, and the triggers for the award of achievements were inappropriate to challenge the student participants. One student reported this aptly:

*“The award of badges should be on an achievement, how they should work is that if you complete a quiz in a different way than the others, you get rewarded for something that others didn’t do differently, or maybe badges for additional challenges that students can select.”* [Student25]

One student expressed the opinion that the award of points and badges should not be tied to the first attempt of completing a module or quiz, but should reflect additional attempts and the learning that has been achieved between attempts. The award of points become the basis of the leaderboard; when the facilitator explained that the leaderboard measures the first attempt on all modules across the year and not necessarily improved learning in a module, the aforementioned student responded with quite an extreme opinion:

*“You don’t need the leaderboard basically it’s pointless.”* [Student13]

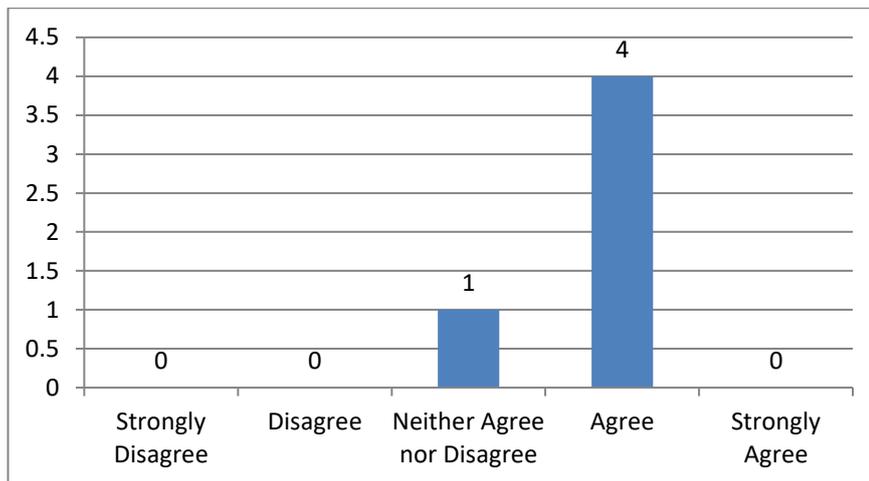
Based on feedback from the survey instrument, support for leaderboard functionality was weak. With reference to Figure 51, two from five respondents agreed with the statement *“The leaderboard motivated me to work hard and progress.”*



**Figure 51: Phase2-Cycle2 - The leaderboard motivated me to work hard and progress.**

In particular two scenarios were explored in the survey instrument and the focus group; the motivational impact of a leaderboard in the case that a student is performing weakly in a subject or in the scenario that a student is performing well in a subject.

With reference to Figure 52, the student response in the survey instrument is positive, four from five respondents agreed with the statement *“In the scenario that I am performing weakly in a subject, a leaderboard would motivate me to work harder to catch up with other students.”*



**Figure 52: Phase2-Cycle2 - In the scenario that I am performing weakly in a subject, a leaderboard would motivate me to work harder to catch up with other students.**

The discussion in the focus group did not fully support the findings from the survey instrument. There were mixed comments from the students:

*“It’s like failing a test it tells you to work harder for the next test; it is telling you to give more attention.”*  
[Student14]

*“There are some people who will be very disappointed that they are at the bottom so instead of trying harder they will try less.”* [Student18]

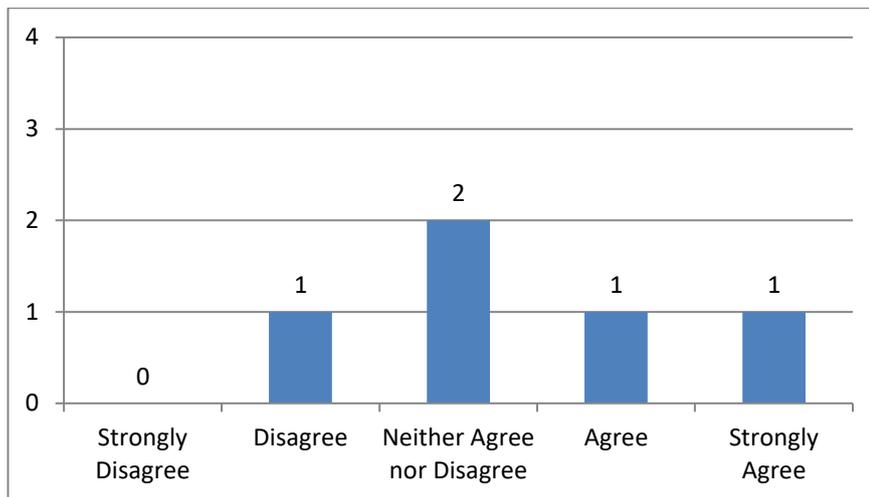
There then followed a discussion on the possibility of an optional leaderboard

*“Maybe you don’t want other people to see your score, or you don’t want to see other people’s score so you don’t get disappointed.”* [Student19]

The upshot of the discussion was that some students, who were initially positive towards the leaderboard in this scenario, became less convinced:

*“I think it leans more towards you being disappointed than towards being encouraged.”* [Student14]

With reference to Figure 53, the student response to the survey instrument is mixed, two from five respondents agreed or strongly agreed with the statement *“In the scenario that I am performing well in a subject, a leaderboard would motivate me to work harder to progress even more.”*



**Figure 53: Phase2-Cycle2 - In the scenario that I am performing well in a subject, a leaderboard would motivate me to work harder to progress even more.**

The discussion in the focus group further identified some students' misgivings with the leaderboard.

*"If you are at the top and 100 points over the 2<sup>nd</sup> place you might lose motivation and not work as hard until they get closer 20 point below you."* [Student 19 and Student 25]

The concern was that rather than focusing on the learning the students might instead refocus more towards competition with their peers.

Based on the findings of Phase2-Cycle2, the e-learning Pedagogy was updated with additional guidance to consider the challenges in implementing extrinsic gamification. Furthermore, in Phase 3 with the exception of levels, extrinsic gamification elements were removed from the e-learning software due to the LMS dependency.

## **C PHASE 3: USAGE OF THE E-LEARNING EVALUATION PROTOCOL**

Education experts provided feedback on the Phase 3 e-learning software evaluation protocol, and a workshop was also used as a vehicle to study teacher usage of the evaluation protocol. The latter findings are presented in summary format in section 6.7.3.2 of the thesis, and specifically Table 86; this appendix further details the findings from the workshop.

## C.1 School Characteristics in Relation to E-learning

The teachers' attendance at a workshop focused on e-learning and pedagogy, indicates a level of interest in e-learning at both the school and teacher levels. However, when asked to discuss the schools' experience in using e-learning software, the teachers in both focus groups indicated their school's limited experience, limited use of e-learning software and a lack of school-wide policy.

*"Partial Experience"* [Evaluator 3]

*"My school provides limited e-learning software mainly because it is for high school students and attendance is required."* [Evaluator 5]

*"Very little. We use Office 365 to facilitate our teaching and learning, and we have the Britannica for schools service for the next academic year."* [Evaluator 1]

*"Very brief"* [Evaluator 13 – Educational]

*"Not so much"* [Evaluator 8]

*"We don't know because it's up to each department."* [Evaluator 4]

A similar picture was revealed when the teachers in group-1 were asked to elaborate on what e-learning software they currently use to support their teaching of Computer Science.

*"None"* [Evaluator 3]

*"For now, none"* [Evaluator 5]

*"I don't use any dedicated e-learning software"* [Evaluator 1]

One evaluator offered a more progressive response:

*"I use many e-learning softwares such as logo, pame and algo."* [Evaluator 13]

However, comparing the above response with that of the previous question indicates this is a personal direction rather than a school strategy. This is further supported by the evaluator's educational background, with an MSc in ICT in Education.

In response to the same question, group-2 offered consensus that there is very limited use of e-learning software in their teaching of Computer Science; with only one teacher commenting on their use of Moodle (the Learning Management System).

Finally, the general response on the frequency of use of dedicated e-learning software was *"never"* to *"rarely."*

Whilst the current findings for these five schools are less than positive, their attendance at the workshop and one school's request for consultation on introducing a school-wide e-learning strategy offer some limited scope for optimism.

## C.2 Teacher Characteristics in Relation to E-learning

The overall findings on the teachers' personal experience of using e-learning software in their teaching are aligned with the findings in the previous section. The majority of teachers in both focus groups have limited or no personal experience of integrating e-learning software into their teaching. Each focus group had one exception; in group-1, Evaluator 5 commented that *"I have been using e-learning software since I was teaching in the USA since 2002. Distance learning was a big thing back then, and universities were expanding on this. I find e-learning software very useful."* In group-2, Evaluator 12 recounted the positive experience she had in supporting students in primary school mathematics e-learning. In contrast, Evaluator 13 offered a more sceptical perspective: *"it is motivating and engaging in the beginning. After a period of time students forget about it and prefer the traditional method such as using their books and notes."*

In contrast, to their limited use of e-learning software, the teachers expressed that they "always" or "very often" use the Internet and the Web to support their teaching.

*"Very often. Even if I remember the material then I use the internet for additional references."* [Evaluator 5]

*"I used it as often as possible from using Internet images to videos and online teaching platforms."*

[Evaluator 13]

Whilst current usage of e-learning software is limited, the teachers in both focus groups showed an understanding of the benefits of e-learning software. When asked in what scenario they would recommend to their students the use of the e-learning software, the teachers recommended:

1. To practice material taught in the lesson,
2. To give additional support to students struggling to keep up, or who don't understand things well,
3. To promote multi-modal learning via animations, audio narrations and trying some examples
4. To replace studying from books,
5. To enable students to undertake extra study, at their own pace,
6. To enable the teacher to observe student progress online,

Evaluator 8 went so far as to say:

*"I would strongly recommend it... Because maybe they can do their practice anytime, anywhere without having them, without pushing them to do right now."*

Both focus groups expressed that e-learning software can have a positive educational impact. Group-2 advised that e-learning software can be a tool at the teacher's disposal to support the teaching and learning process. This tool could potentially be used to increase student practice, promote healthy student competition, encourage students to try more and potentially reduce teaching time.

In a similar vein, group-1 asserted that e-learning software is a tool that if implemented correctly can have a great educational impact.

*"It will have a positive impact as long as it is accepted by the students as a helpful software... More practice, less traditional teaching (talking for hours)." [Evaluator 3]*

*"I believe that it could potentially have a great educational impact." [Evaluator 5]*

*"Implemented correctly, e-learning software can have a very positive effect. The teacher cannot be with every student at all times; the software can." [Evaluator 1]*

*"... it would have a positive educational impact for engaging all the students. For example, some prefer to study alone and some need more visual content and context to comprehend and learn." [Evaluator 13]*

*"... a second voice to explain a complex topic in a different way to me" [Evaluator 1]*

In addition, both groups affirmed that e-learning software could have positive impact on student motivation towards computing. Group-2 offered a general confirmation, without elaborating in detail; whereas group-1 gave more detail:

*"I think it would have some sort of motivation since there are clear goals and rewards." [Evaluator 3]*

*"Yes, it could be a great motivator because it combines 3 important aspects; Animation, Narrative and Problem solving." [Evaluator 5]*

*"The less able students would probably be more motivated because they could succeed in their own time, and the e-learning platform would allow them to try things without the risk of appearing foolish in front of their peers when they get things wrong." [Evaluator 1]*

*"I believe it would have a positive feedback motivating and engaging them more for the computing subject." [Evaluator 3]*

Both groups acknowledged that there are barriers that discourage them from using e-learning software in their teaching. Group-2's concerns were primarily focused on the quality of the software, such as: if it was not well structured, if the navigation was not well designed, or the software as not user friendly. Lastly, and most importantly, whether it covers the learning objectives. Group-1's concerns also touched upon the maturity of the software/content on offer, but elaborated further on the socio-political and technology barriers:

*"The school, the students, other colleagues, time limitation" [Evaluator 3]*

*"It does not depend solely on myself, but on my supervisor. I can bring it to their attention though because I believe that it would be very beneficial." [Evaluator 5]*

*"Not being able to have the appropriate technology to support the software and sometimes students are not familiar with technology and prefer to read from books and teachers to teach by book or by test." [Evaluator 13]*

### C.3 Teacher Feedback on the Evaluation Protocol

The broad findings from the workshop were that the teachers had limited or no experience in selecting or evaluating e-learning software. However, the teachers in both focus groups expressed that if they were called upon by their schools, they would get involved in an e-learning evaluation. More importantly, both focus groups expressed that they could use the heuristics and the evaluation procedure described in the workshop to evaluate e-learning software.

*"Yes, they are very important"* [Evaluator13]

*"Right now, I don't think that I am very comfortable in doing so. However, if the need arises then I will be able to use both."* [Evaluator 5]

*"Sure. It would help to have a formal structure for the evaluation and for feeding back to management."* [Evaluator 1]

After direct experience of using the e-learning evaluation protocol, both groups offered limited feedback on how to improve the process. The relative lack of feedback on how to improve the evaluation process, in conjunction with the response to the previous question, is taken as a positive indicator that the evaluation protocol is appropriate for use by teachers, but with room for refinement to improve the efficiency of the process.

Considering the feedback of both groups, one evaluator suggested that there could be less explanation on the heuristics, whereas another evaluator felt the explanation was clear, but some examples, where applicable, would be nice.

Similarly, there was minimal feedback on the explanation of the evaluation procedure; one evaluator requested more direct explanation, whereas another evaluator offered the following feedback:

*"Easy enough to understand for an experienced professional. I'm not sure how well I'd have understood it all as a newly-qualified teacher, but I believe I'd have been able to undertake the process properly."* [Evaluator 1]

The teachers gave more feedback regarding the hands-on activity of evaluating the software. A recurring theme from three evaluators was the limited time allocated to the evaluation activity:

*"More time for the evaluation activity"* [Evaluator 3]

*"The nature of the seminar forced this to be a bit hurried, and we had to work off incomplete data. A full evaluation would not have suffered from such issues, so I do not feel there is need for improvement here."* [Evaluator 1]

*"We need more time... we need more time to evaluate it rightly. There are some questions we can't give you a correct answer because we don't know the software, to evaluate the software to give you a proper answer."* [Evaluator 8]

When asked whether they would be willing to spend the extra time on the evaluation activity group-2 confirmed that they would.

Another significant point raised by one evaluator is to have the heuristics in front of them whilst doing the evaluation, so the evaluators are able to remember the meaning and criteria for each one. Although entirely valid, this comment was caused by a common misconception brought about by the structure and timelines of the workshop. Due to the timelines of the one-day workshop, the responses of the individual evaluations were collected in an online survey instrument; this enabled the facilitator to analyse the responses within a 15-minute window and present back to the evaluators a consolidated response summary during the debrief session. One limitation of the online survey instrument is that it could not represent the richness of the heuristics and their underlying criteria. With this limitation in mind, the teachers were requested to also use their paper copy of the evaluation protocol document as a reference for the heuristics and criteria. It is likely that many did not take on-board this guidance and instead worked from memory. In a typical evaluation scenario, there would usually be more time between the individual evaluations and the evaluation debrief. This means that the evaluators would use the evaluation protocol report to record their individual results and would, therefore, have the heuristics and criteria readily accessible.

Despite the previous point, there was no comment from the evaluators regarding the recording of individual evaluation results. The only related comment was with regards *“a little more explanation”* on '0' and '-4' scores in the level of support response scale. In fact, this was discussed in the presentation of the evaluation protocol; however, considering the importance of accurate quantitative results, it is a valid point that the response scales must be clear to all facilitators and the evaluators.

Another area that received minimal feedback from the evaluators was the group debrief session. Despite it being apparent that the time allocated (45 minutes) was not enough time to complete the evaluation debrief; none of the evaluators commented on this. In fact, in group-2, even after being prompted to do so, no teacher commented.

Potentially, this is because the format of a 1-day workshop created a visible time pressure in which every minute was made to count. Verbal comments from the teachers expressed that the workshop was a success, and when asked to comment on the time allocated to the specific activities, one evaluator expressed:

*“This was fine. The day was short, and it was used well.”* [Evaluator 1]

## **C.4 Workshop Timeline Analysis**

Following on from the previous section and the evaluators' comments, or relative lack of comment, on activity durations, a timeline analysis of the workshop agenda was carried out. This analysis is important since teachers are busy professionals with limited time, thereby we must understand the typical duration of an evaluation activity and establish the most effective use of time. Please refer to Table 5 for the agenda of the one-day workshop.

Activity	Time
Introduction and getting to know each other	09:00 – 09:30
E-Learning Heuristics.	09:30 – 10:45
Morning coffee and snack break.	10:45 – 11:00
E-Learning Heuristics .	11:00 – 12:15
Outline the procedure for the E-Learning Evaluation.	12:15 – 12:30
Lunch	12:30 - 13:00
Evaluate an e-learning software (individually).	13:00 – 14:30
Afternoon coffee and snack break.	14:30 – 14:45
Group debrief meeting on evaluation results.	14:45 – 15:30
Focus group - Your thoughts on the day (input into research).	15:30 – 16:30

**Table 5: Evaluation Protocol Workshop Agenda (sourced from workshop introductory presentation)**

As previously mentioned, a workshop is not a standard approach for an e-learning evaluation activity and this workshop was constrained to one-day duration. Please refer to Table 6 for a breakdown of planned and actual durations.

Activity	Planned Duration	Actual Duration
Introduction and getting to know each other	30 minutes	30 minutes
Instruction on E-Learning Heuristics	2 hours 30 minutes	2 hours 35 minutes
Outline the procedure for the E-Learning Evaluation	15 minutes	15 minutes
Evaluate the E-Learning software (individually)	1 hour 30 minutes	1 hour 15 minutes
Summarise individual responses (researcher only)	15 minutes	20 minutes
Group debrief meeting on evaluation results	45 minutes	1 hour 38 minutes
Write up the Group Evaluation Report (facilitator)	2 hours	6 hours (incl. transcription)
Review and confirm the Group Evaluation Report	1 hour	Unknown

**Table 6: Workshop activity durations**

The morning workshop sessions went largely to plan; however, a minor overrun on the “Instruction on E-Learning Heuristics” and an overrun in morning coffee break meant the session to “Outline the procedure for the E-Learning Evaluation” was moved after lunch. This, in turn, had a knock-on effect to shorten by 15 minutes the session to “Evaluate the E-Learning software (individually).” Overall, considering the afternoon break and the need to consolidate individual responses, the group-1 debrief session started 15 minutes late, and the group-2 debrief session approximately 10 minutes late.

### **C.4.1 Introduction and Getting to Know Each Other**

An introductory session is mandatory; however, in the scenario that the evaluator group already know each other and have prior knowledge of the heuristics and the evaluation protocol, then this session can theoretically be reduced from 30 minutes to 15 minutes.

### **C.4.2 Instruction on E-learning Heuristics**

Instruction on the e-learning heuristics is a mandatory session for evaluators, who have none or minimal prior experience of the heuristics. However, this session can be removed if the evaluators have knowledge and experience of the heuristics.

The restrictions of the workshop agenda limited this session to 2 hours 35 minutes; however, as commented by one evaluator and acknowledged by the instructor. The heuristics session was slightly rushed and was not enriched with examples and practice activities. Ideally, this session should be planned for approximately 3 hours.

### **C.4.3 Outline the Procedure for the E-learning Evaluation**

Instruction on the procedure for the e-learning evaluation is a mandatory session for evaluators, who have none or minimal prior experience of the evaluation protocol. Considering the importance of following the protocol it is recommended that even evaluators with prior experience of the protocol be given a 15-minute refresher and evaluators with no prior experience may require up to 30 minutes (including a questions and answers session).

### **C.4.4 Evaluate the E-learning Software (individually)**

The evaluation of the e-learning software consists of a free-flow exploration, followed by an in-depth walkthrough; the latter includes the parallel recording of the evaluation results in the evaluation protocol document. This activity is highly dependent on the typical learning duration of the e-learning software. The e-learning software evaluated in the workshop has a typical learning duration of 1 hour. Due to the restrictions of the workshop agenda 1 hour and 15 minutes was allocated to the evaluation. As commented by multiple evaluators and confirmed by researcher observation, the time allocated was too short; it is theorised that the minimal time for the individual e-learning evaluations should be approximately 2.5 times the typical learning duration of the software.

### **C.4.5 Summarise Individual Responses (Researcher only)**

Due to the one-day workshop format, the debrief session followed almost immediately after the individual evaluation activity (after a planned 15-minute break). The evaluation protocol recommends that the individual evaluation results are recorded in a structured format; for this purpose, the e-learning evaluation protocol document also acts as a result recording template. However, as outlined above, the time between individual and debrief sessions meant it was impossible for a facilitator to consolidate the

results from 4 – 5 documents manually. Hence, an online instrument was created for the evaluators to record their results. The facilitator was then able to download a consolidated summary of the evaluator responses within the allotted 15-minute duration. In the scenario that the evaluation schedule and the availability of the evaluators are not so limited, then it is possible to split the evaluation across multiple days. Furthermore, it becomes possible for the facilitator to consolidate the results from the individual evaluation protocol documents manually. Considering an average of four evaluators and an average of 45 minutes per document would result in approximately 3 hours of facilitator work to consolidate the results.

#### **C.4.6 Group Debrief Meeting on Evaluation Results**

The duration of the debrief meeting does not have a strong dependency on the typical learning duration of the software; it is more contingent on the number of heuristics (which is fixed) and the number of applicable heuristics (which is unknown until after the individual evaluations). The duration of the debrief session is though dependent on the number of Learning Objectives covered by the software.

Group-1 completed the debrief session, covering 6 Learning Objectives and 21 heuristics (40 heuristics and sub-heuristics), in 1 hour and 38 minutes. However, it should be noted that this debrief session was run at quite a fast pace and with more emphasis towards securing consensus on the quantitative results.

Group-2 partially completed the debrief session, covering 6 Learning Objectives and up to heuristic 11.1 (17 heuristics and sub-heuristics), in 1 hour. This is approximately 50% of the debrief scope. However, it should be noted that this debrief session was run at a slightly slower pace, as compared to group-1, and with more emphasis towards qualitative feedback on issues and areas of improvement.

Considering the findings from both groups, it is recommended the debrief session for software with six Learning Objectives should be scheduled for 2 hours. If the software contains significantly more or less Learning Objectives, these can be estimated at approximately 5 minutes per Learning Objective.

#### **C.4.7 Write up of the Group Evaluation Report (Facilitator)**

For the purposes of research validity, the debrief sessions were recorded either with video (group-1) or audio (group-2); these were then transcribed. This transcription process took an almost interminably long time. However, it should be noted that in a typical e-learning evaluation, whether audio-visual recording is used, is at the facilitator's discretion and more importantly a detailed transcription is not necessary or recommended. Instead, the facilitator should focus on taking reliable notes during the debrief session and if necessary, referring to any audio-visual recording as merely a refresher. Following these guidelines, the write-up of the group evaluation report should take between 1 (write up based on notes) to 2.5 hours (write up based refresher review of audio-visual recording).

A more concerning finding is that using the e-learning evaluation protocol document for the final group evaluation report creates an overhead in writing up the report. The document describes the protocol, the heuristics, and their underlying criteria in detail, creating a document that is 75 pages long. This creates an unnecessary overhead in the teachers' final review and confirmation of the group report since the

actual material requiring review is likely to be circa 10 pages. Moreover, in the context of a voluntary research study, being presented with a 75-page document is demotivating and affected the teacher response rate.

A more appropriate group report template will be developed that focuses on the 1-page Evaluation Results excel, followed by the qualitative comments agreed by the evaluators during the debrief session. Considering, 1 cover page, 1-2 introductory pages, the Evaluation Results excel, and qualitative comments for approximately 4-5 heuristics per page, estimates a document of fewer than 15 pages.

#### **C.4.8 Review and Confirm Group Evaluation Report**

Building on the analysis from the previous section it is postulated that the group evaluation report should typically contain less than 15 pages of review material. This is estimated to take between 45 minutes to 1 hour for a teacher to review. Due to a limited response from evaluators after the workshop, this remains a theorised estimate that has not been verified with the evaluators.

#### **C.4.9 E-Learning Evaluation: Estimated Duration**

The following best and worst-case evaluation scenarios consider:

1. The previous timeline analysis,
2. E-learning software of 1-hour typical learning duration and six Learning Objectives, and
3. Evaluators who are double experts.

The worst-case scenario additionally considers the evaluators to have zero or minimal experience with the heuristics and evaluation protocol, and the best-case scenario considers the evaluators experienced with the heuristics and evaluation protocol.

It should be noted that the following estimates are not based on extensive empirical results but based on findings from the workshop and logical inference. They are offered purely as guidelines for planning purposes for those wishing to undertake an e-learning evaluation.

With reference to Table 7, the worst-case scenario requires approximately 14 hours from the facilitator and 9 hours 30 minutes from each evaluator. The best-case scenario requires approximately 6 hours 15 minutes from the facilitator and 5 hours 45 minutes from each evaluator. It follows that the best-case scenario can be accommodated within 1 day, whereas the worst-case scenario is better planned across multiple days.

	Worst Case		Best Case	
	Facilitator	Evaluators	Facilitator	Evaluators
Introduction and getting to know each other	00:30	00:30	00:15	00:15
Instruction on E-Learning Heuristics	03:00	03:00	00:00	00:00
Outline the procedure for the E-Learning Evaluation	00:30	00:30	00:15	00:15
Evaluate the e-learning software (individually)	02:30	02:30	02:30	02:30
Summarise individual responses (Researcher only)	03:00	00:00	00:15	00:00
Group debrief meeting on evaluation results	02:00	02:00	02:00	02:00
Write up Group Evaluation Report (Facilitator)	02:30	00:00	01:00	00:00
Review and confirm Group Evaluation Report	00:00	01:00	00:00	00:45
<b>Total</b>	<b>14:00</b>	<b>09:30</b>	<b>06:15</b>	<b>05:45</b>

Table 7: Estimated durations for best and worst-case evaluation scenarios.

## C.5 Restructuring the Evaluation Procedure

One education expert, with extensive background in qualitative education research, offered some recommendations to streamline the evaluation process. These recommendations include:

1. The removal of individual evaluations in lieu of a single group evaluation,
2. The evaluation group taking ownership during the group evaluation session to also update the group evaluation report,

Such an approach simplifies the evaluation process by:

1. Removing the individual evaluations in favour of a single extended group evaluation,
2. Removing the activity to summarise individual evaluation results into a consolidated summary,
3. Removing the group debrief session,
4. Adjusting the facilitator led activity to write-up the group evaluation report, to a group-based activity executed during the group evaluation activity, and
5. Removing the activity for evaluators to review and confirm the group evaluation report, since it is now a group deliverable.

This approach undeniably offers benefits by radically simplifying the evaluation process and thereby significantly reducing the associated efforts and durations. However, there remain concerns with the suggested approach, which ultimately led to the approach not being adopted at this stage of the research.

The exact form and format of the proposed (above) group evaluation activity are currently an unknown which would require further investigation and research in order to define adequately. The current evaluation protocol, whilst extensive, is developed based on existing best practice from research in heuristics evaluations. The current evaluation protocol offers documented benefits that would potentially be jeopardised if the new approach is adopted.

To avoid potentially subjective and/or incomplete evaluation feedback, it is recommended to engage multiple evaluators and aggregate the evaluations from several evaluators. This capitalises on the considerable non-overlap between the responses of different evaluators. Bypassing the individual evaluations presumes that the individual responses will still make their way to the surface in a group

session; whereas there is a significant risk that the group will settle too quickly on a single view rather than aggregating individual responses.

A single group evaluation will proceed at the pace of the group and will have single group view of the software; this, in turn, increases the risk of potentially missing parts of the software or missing areas of feedback.

The individual evaluations enable the evaluators to become knowledgeable of the software and to develop their own opinion that they are better able to discuss and defend. Bypassing the individual evaluations means that dominant evaluators can have more of an impact in biasing the group towards their own personal opinion. With less individual preparation, other evaluators are less able to promote competing or supplementary feedback.

In addition, the debrief session offers a valuable reflection point, in which individual misconceptions (on the heuristics, the learning objectives, the education setting and the software) can be clarified and resolved. The opportunity for such reflection is not present, whilst simultaneously walking through the software, discussing, and in parallel documenting the group feedback.

The overriding concern with adjusting the evaluation protocol towards a single group evaluation is that it bypasses key procedure steps and controls that could potentially reduce the quality of the evaluation. This is though, an area to be potentially investigated in future works.

## **C.6 Reliability and Validity of Evaluation Results**

The Level-3 e-learning software was designed with content and pedagogical quality in consideration. However, as an e-learning prototype, within a wider set of four e-learning software, it cannot be judged as exemplary. It would not be expected to receive a maximum evaluation score, more realistically it is a moderate to good implementation. Group-1 undertook a full evaluation of the Level-3 e-learning prototype and reported a Content Quality of 88%, a Pedagogical Quality of 70% and overall Educational Value of 62%. The detailed analysis is included in Appendix V. This evaluation offers preliminary signs of validity since it is broadly aligned with the expectations for this e-learning software.

There are further positive indicators regarding the validity of the evaluation results from both groups. As mentioned, the e-learning software under evaluation is part of a 4-level set of e-learning software, as such, offers less support to some heuristics as compared to other levels. Level-3 does not explicitly offer any collaborative or social-learning support. Both groups accurately reported the following heuristics as *"0 Neither Supports NOR Counteracts."*

- Heuristic 9: Use social-interaction to increase learning and promote higher-order thinking.
- Heuristic 11: Use collaborative learning activities.
- Heuristics 11.1: Support collaborative and situated learning via mobile devices.

After discussion, group-1 elaborated that heuristic 11.1 is not applicable in this particular learning context. Group-1 also responded correctly that heuristic 12 “*Develop and nurture networks to support learning*” was also not-supported; group-2 did not reach this point in the evaluation debrief.

Comparative to other levels, level-3 also offers less support for exemplifying Computational Thinking. Both groups accurately reflected this reduced support, by reporting the level of support as 2 (from 4).

Additionally, both groups reported concern over the software’s level of support for engaging students in the Zone of Proximal Development (ZPD). Group-1 responded that the software offered reduced support for ZPD (two from four), commenting that there was a learning curve, but individual ZPD was not supported. Group-2 took a more assertive stance by reporting that engaging learners in a challenge and targeting learning towards the ZPD was not supported (zero from four), this response is further explored later in this section.

As per the intended purpose, the e-learning evaluations and in particular the debrief sessions added great value in identifying specific pedagogical shortcomings and recommendations to improve the software.

One simple example, which seems obvious in hindsight, is the pre-training screen on Course Navigation and Learning Icons (refer to Figure 54). It was commented that the screen was just too busy; one evaluator candidly referred to this screen as a “wall of icons.” This tangibly leads to an improvement to break this screen into three internal sub-screens, which better adheres to heuristic 19 “*Optimise essential processing by segmenting learning material and providing pre-training.*”

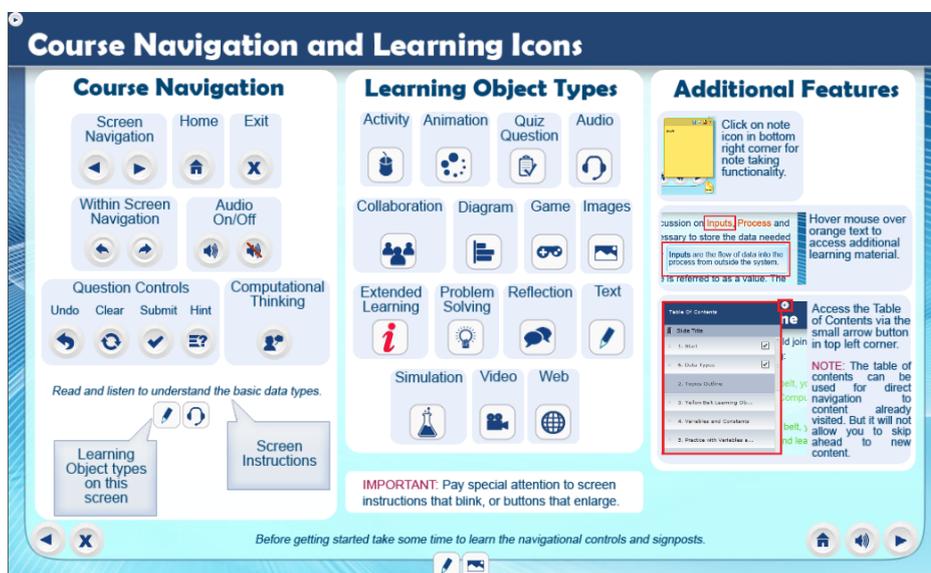


Figure 54: Screenshot of Course Navigation and Learning Icons screen.

Additional, feedback on pedagogical shortcomings and suggestions to improve the software included the following:

Group-1 responded that the level of challenge of the software was correct for a typical student, but may not support weaker students to the extent necessary. This flowed into a discussion that the level of challenge for high-performing students may also be insufficient. This discussion was also mirrored at

length in group-2. These discussions culminated in concrete suggestions from both groups on how to improve the software, such as:

1. The creation of a large pool of examples, activities and questions that offer different contexts and different levels of challenge,
2. That a smaller subset of examples, activities and questions are randomly and dynamically selected from this pool, based on the student's progress and performance up to that point, and
3. That the varying level of challenge in questions and activities is represented by increasing points, which in turn should positively influence satisfaction and motivation.

Group-1 also responded that the software only "Slightly Supports" the provision of explanatory feedback. The group's additional comments were illuminating; explanatory feedback was judged present, but not at the level and depth considered appropriate. It was commented that students need an explanation on why they got it wrong, why they got it right, and possibly how they could get it even more right. In particular, it was commented that the current feedback is overly focused on when students made mistakes.

Group-2 identified an inaccuracy in one of the flowchart diagrams since the decision element was not correctly labelled with "True" "False" flows. Additionally, group-2 gave concrete recommendations on using more visual representations, more explanation of variables and constants, and more analysis of the different data types, in particular, more focus on how data types affect arithmetic calculations. However, as will be discussed in more detail later in this section, these comments may have been unduly influenced by an incorrect perception for the Educational Setting for the software.

Group-2, in particular, had some rich discussion in their debrief session. There were lengthy discussions on the most appropriate scheme of work and lesson plans to teach algorithms, computational thinking, flowcharts and pseudocode. These discussions were largely reflective in nature and in some cases circular. The initial focus was somewhat pessimistic concentrating on what the level-3 software did not include, but eventually, the group reached alignment on an effective scheme of work: towards flowcharts, followed by pseudocode and finally programming.

*"...this level is only about flowcharts; pseudocode is the blue belt... It's not about everything in programming, it's only about the first steps of how to get involved in programming using one of the methods; using flowcharts as a visual representation."* [Evaluator 12]

There then followed an interchange in which group-2 started to align on an effective scheme of work.

*"Yes, actually to teach the flowcharts you must not show everything you must not show everything before, like sequence, selection and iteration, this presentation gives it all in one presentation."*

[Evaluator 14]

*"Maybe it was a summarised."* [Evaluator 4]

*"Yeah, when you cover in pseudocode you must refer again to this, in order to combine both the pseudocode and flowchart."* [Evaluator 14]

“You will repeat the theory behind, let’s say, the principals behind, so you will teach them the principles for the flowcharts and then you will repeat yourself when you are using pseudocode, so they will be forced there, if I can use this word, to understand the principles.” [Evaluator 12]

Group-2’s final position is encouraging in that it aligns well with the instructional design of the flowchart e-learning software (Level-3) in which variables and constants, data types, arithmetic and Boolean expressions, sequence, selection and iteration are taught concisely and not in the level of detail necessary for coding. Level-4 on pseudocode refers back to and reinforces this material and both act as precursors for the students’ progression to programming.

“Some more principles are let say clearly explained or more explained when using pseudocode or using a programming language, that’s why when using flowcharts students are somewhat ok mmm, then when using pseudocode you have more students saying I have this in my mind I can explain and solve problems, and then when they have programming language they have things clearer there.”

[Evaluator 12]

### C.6.1.1 Comparison of Group-1 and Group-2 Heuristic Evaluation Results

The reliability and validity of the evaluation protocol are further evidenced by a direct comparative analysis of the group-1 and group-2 evaluation results up to heuristic 11.1. Referring to Figure 55 and Figure 56, there is a notable similarity on the Pedagogical Quality results of 59% and 56%.

Heuristics						
ID	Heuristic Title	Importance of Heuristic in Learning Context	Support for Heuristic	Weighted Support for Heuristic	Theoretical Maximum Support	
1	Use authentic educational material, examples and activities.	4 Extremely Important	3	3	4	
1.1	Ensure the currency of learning material.	3 Very Important	3	2.25	3	
2	Prompt reflective practice to support learning.	3 Very Important	2	1.5	3	
3	Make expert and learner thinking processes explicit.	3 Very Important	2	1.5	3	
4	Use problem based learning (PBL) to facilitate learning.	4 Extremely Important	4 Strongly Supports	4	4	
4.1	Use worked examples to support problem based learning.	4 Extremely Important	4 Strongly Supports	4	4	
5	Integrate learning into long-term memory by using authentic examples, and non-trivial practice and problems.	4 Extremely Important	3	3	4	
6	Support problem solving through Computational Thinking.	4 Extremely Important	3	3	4	
6.1	Build a foundation for Computational Thinking.	4 Extremely Important	3	3	4	
6.2	Exemplify Computational Thinking in problem solving activities.	4 Extremely Important	2	2	4	
7	Distribute well-designed practice activities across the lesson to support learning.	4 Extremely Important	2	2	4	
7.1	Provide explanatory feedback to practice activities to promote learning.	4 Extremely Important	1 Slightly Supports	1	4	
8	Provide scaffolding to advance learning progress.	3 Very Important	3	2.25	3	
9	Use social-interaction to increase learning and promote higher-order thinking.	3 Very Important	0 Neither Supports NOR Counteracts	0	3	
10	Engage learners in a challenge; target learning towards the zone of proximal development (ZPD).	4 Extremely Important	2	2	4	
11	Use collaborative learning activities.	3 Very Important	0 Neither Supports NOR Counteracts	0	3	
11.1	Support collaborative and situated learning via mobile devices.	0 Not Applicable	0 Neither Supports NOR Counteracts	0	0	
<b>Pedagogical Quality:</b>				<b>34.5</b>	<b>58</b>	<b>59%</b>

Figure 55: Group-1 evaluation results up to heuristic 11.1

Heuristics					
ID	Heuristic Title	Importance of Heuristic in Learning Context	Support for Heuristic	Weighted Support for Heuristic	Theoretical Maximum Support
1	Use authentic educational material, examples and activities.	4 Extremely Important	3	3	4
1.1	Ensure the currency of learning material.	3 Very Important	4 Strongly Supports	3	3
2	Prompt reflective practice to support learning.	4 Extremely Important	3	3	4
3	Make expert and learner thinking processes explicit.	3 Very Important	3	2.25	3
4	Use problem based learning (PBL) to facilitate learning.	4 Extremely Important	3	3	4
4.1	Use worked examples to support problem based learning.	3 Very Important	3	2.25	3
5	Integrate learning into long-term memory by using authentic examples, and non-trivial practice and problems.	3 Very Important	0 Neither Supports NOR Counteracts	0	3
6	Support problem solving through Computational Thinking.	4 Extremely Important	3	3	4
6.1	Build a foundation for Computational Thinking.	4 Extremely Important	3	3	4
6.2	Exemplify Computational Thinking in problem solving activities.	3 Very Important	2	1.5	3
7	Distribute well-designed practice activities across the lesson to support learning.	3 Very Important	3	2.25	3
7.1	Provide explanatory feedback to practice activities to promote learning.	3 Very Important	3	2.25	3
8	Provide scaffolding to advance learning progress.	3 Very Important	3	2.25	3
9	Use social-interaction to increase learning and promote higher-order thinking.	3 Very Important	0 Neither Supports NOR Counteracts	0	3
10	Engage learners in a challenge; target learning towards the zone of proximal development (ZPD).	3 Very Important	0 Neither Supports NOR Counteracts	0	3
11	Use collaborative learning activities.	3 Very Important	0 Neither Supports NOR Counteracts	0	3
11.1	Support collaborative and situated learning via mobile devices.	2 Moderately Important	0 Neither Supports NOR Counteracts	0	2
Pedagogical Quality:				30.75	55

Figure 56: Group-2 evaluation results up to heuristic 11.1

A more in-depth review of the group-2 responses demonstrates the potential for even closer alignment. For heuristic 5, group-1 gave a weighted support of 3, whereas group-2 reported that the e-learning software neither supported nor counteracted the heuristic (i.e. 0 from 4). The concern on this result is that heuristic 5, is dependent on eight other heuristics, of which seven were evaluated by group-2: five heuristics were rated as 3, one was rated as 2, and one was rated as 0. This gives a warning flag that the group-2 response for heuristic 5 should have been above zero. In addition, a review of the individual evaluator responses to this heuristic show that three of the five evaluators gave positive support values (1, 3 and 4). The previous points prompted a review of the debrief session transcript which showed that during the debrief session the focus of the discussion concentrated not on the eight evaluation criteria for this heuristic, but on the title only. In fact, the group-2 evaluation of this heuristic was narrowed to focus only on one part of the title; whether there were non-trivial practice activities. The dominance of two evaluators on this specific point led to a group decision to mark the level of support for this heuristic as 0. It is therefore reasonable to postulate that for heuristic 5 a group response of 2 or 3 is more appropriate for group-2; this in turn would have brought the pedagogical quality rating to 59% or 60%.

As previously discussed, there is a similar concern for heuristic 10; both groups recorded concerns on the software's support for engaging student's in a challenge and targeting the ZPD. Group-1 gave weighted support of 2; however, group-2 took quite an extreme position by recording that the software neither supports nor counteracts this heuristic (i.e. 0). This group response is significantly different from the individual evaluator responses in which two evaluators responded 4, one evaluator responded 3, one evaluator responded 1, and one evaluator responded 0. Again, it is reasonable to postulate that a group response of 1 or 2 is maybe more appropriate; this, in turn, would have brought the pedagogical quality rating to 57% or 59%.

In short, a small adjustment to either of these heuristics in keeping with the above analysis would have brought the pedagogical quality rating of both groups to be almost identical.

### C.6.1.2 Comparison of Group-1 and Group-2 Learning Objective Evaluation Results

In contrast to the previous section, a similar comparative analysis of the group-1 and group-2 evaluation results for Learning Objectives throws concern on the reliability and validity of the evaluation protocol. Referring to Figure 57 and Figure 58, there is a significant difference on the Content Quality results of 88% and 27%.

Learning Objectives						
ID	Learning Objective	Importance of Learning Objective	Support for Learning Objective	Weighted Support for Learning Objective	Theoretical Maximum Support	
1	Understand the concepts of variables and constants	4 Extremely Important	4 Strongly Supports	4	4	
2	Understand the concept of data types	3 Very Important	3	2.25	3	
3	Be able to use arithmetic calculations in your algorithms	4 Extremely Important	3	3	4	
4	Be able to use Boolean expressions in your algorithms	4 Extremely Important	3	3	4	
5	Using flowcharts determine the purpose of simple algorithms and explain how they work	4 Extremely Important	4 Strongly Supports	4	4	
6	Using flowcharts explain simple algorithms in terms of their inputs, processing and outputs.	4 Extremely Important	4 Strongly Supports	4	4	
Content Quality:				20.25	23	88%

Figure 57: Group-1 Evaluation Results for Learning Objectives

Learning Objectives						
ID	Learning Objective	Importance of Learning Objective	Support for Learning Objective	Weighted Support for Learning Objective	Theoretical Maximum Support	
1	Understand the concepts of variables and constants	4 Extremely Important	-1 Slightly Counteracts	-1	4	
2	Understand the concept of data types	4 Extremely Important	-1 Slightly Counteracts	-1	4	
3	Be able to use arithmetic calculations in your algorithms	4 Extremely Important	3	3	4	
4	Be able to use Boolean expressions in your algorithms	4 Extremely Important	3	3	4	
5	Using flowcharts determine the purpose of simple algorithms and explain how they work	4 Extremely Important	3	3	4	
6	Using flowcharts explain simple algorithms in terms of their inputs, processing and outputs.	3 Very Important	-1 Slightly Counteracts	-0.75	3	
Content Quality:				6.25	23	27%

Figure 58: Group-2 Evaluation Results for Learning Objectives

A deeper analysis offers a partial explanation of this discrepancy. Group-2 responded that for three of the six learning objectives, they felt that the e-learning software slightly counteracted the successful learning of the learning objectives. A negative value for support of learning objectives is generally reserved for e-learning software whose learning content is factually incorrect or inaccurate in terms of a given syllabus, or that in some manner explicitly obstructs the learning of the learning objective. As the instructional designer and developer for the level-3 e-learning prototype, I acknowledge my perspective may be considered biased due to my direct involvement; however, it is doubtful that the learning content was inaccurate or poorly designed to the extent that it would obstruct learning on these topics. This assertion is made since the learning content was synthesised from official material from the three main examination boards and education experts from the Computing at Schools Network. Furthermore, with reference to Table 8, it is evident that for learning objectives 1, 2 and 6; the responses from individual evaluators, and the mean, mode and median values, are all radically different to the debrief responses. This is also reflected visually in Figure 59.

	E14	E08	E02	E04	E12	Mean	Mode	Median	Debrief
LO1	4	4	4	4	2	3.6	4	4	-1
LO2	4	4	4	4	-1	3	4	4	-1
LO3	3	4	4	4	3	3.6	4	4	3
LO4	3	3	4	4	4	3.6	4	4	3
LO5	3	4	3	3	3	3.2	3	3	3
LO6	4	3	3	3	2	3	3	3	-1

Table 8: Group-2 Evaluation of support for learning objectives (LO).

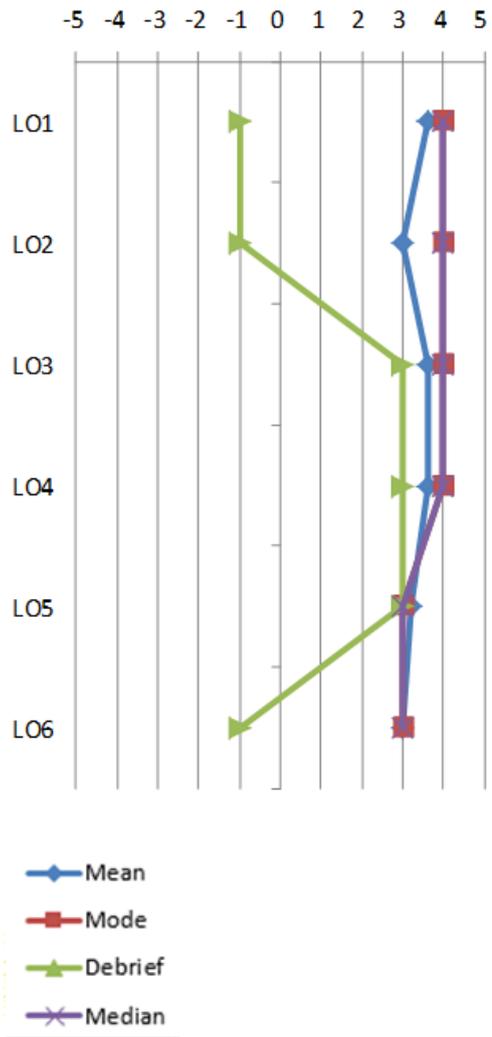


Figure 59: Group-2 Evaluation of Support for Learning Objectives

The previous points indicate that these responses are potentially outliers or at least atypical. Upon further investigation, the facilitator of the group-2 debrief session verified the debrief responses, reflecting the agreement of the group majority, and confirmed there were no transcription errors. Unfortunately, the audio recording of the group-2 debrief session is of inconsistent quality and does not give conclusive reasoning for why the group responded this way. However, an analysis of the audio did identify that group-2 had a significant challenge in aligning on the given education setting (please refer to Appendix O). A significant portion of their debrief discussion reflected an incorrect perception that the level-3 software should include pseudocode and that the coverage of data types, and variables and constants

should be at a level to prepare students for coding (programming). This incorrect perception would explain a low response for the level of support for learning objectives 1 and 2, but would not explain the group’s assertion that the software counteracted the learning of these areas. Furthermore, it does not explain that that for software dedicated to the instruction of flowcharts, that group-2 responded that it counteracts the learning of flowcharts in the context of inputs, processing and outputs (LO6). A follow up was sent to the group-2 evaluators to get further clarification on their debrief responses, but unfortunately none of the evaluators responded.

### **C.6.1.3 Results of Correlation Analysis**

The findings from the previous two sections are further verified by a correlation analysis done between the mean, mode, median, and debrief responses for both groups. Both groups demonstrate the trend that the mean, mode and median typically offer a strong correlation with the group’s final debrief response.

The most notable exception to this is the group 2 - Learning Objective Support correlation (refer to Table 9) which shows: that correlations are not statistically significant, the lowest mean to debrief correlation, and zero correlation between mode and debrief, and median and debrief. These findings mirror the findings of Table 8 and Figure 59 which show that the debrief responses for learning objectives 1, 2 and 6 do not reflect normal evaluator behaviour and are atypical.

		Mean	Mode	Debrief
Mode	Pearson Correlation	.60	1	
	Sig. (2-tailed)	.21		
	N	6	6	
Debrief	Pearson Correlation	.49	.00	1
	Sig. (2-tailed)	.33	1.00	
	N	6	6	6
Median	Pearson Correlation	.60	1.00	.00
	Sig. (2-tailed)	.21	.00	1.00
	N	6	6	6

**Table 9: Group 2 - Learning Objective Support Correlation**

## **C.7 Applicability of Learning Objectives and Heuristics to the Educational Setting**

An important area requiring discussion, is the evaluator activity to specify whether learning objectives and heuristics are applicable to the given educational setting. This is important because it finalises the scope of the evaluation. In this evaluation, all the learning objectives were applicable within the given educational setting, therefore the evaluators were informed that they did not need to evaluate their

applicability. In contrast in this evaluation, not all heuristics were necessarily applicable to the given educational setting. With this in mind, there is some concern that only one heuristic was judged by the evaluators to be non-applicable; heuristic 11.1 Support collaborative and situated learning via mobile devices. Considering the positive evaluator feedback on the heuristics in section A.4, this result is partially explained by the evaluators positive recognition that the heuristics give value, and are generally applicable to most educational settings. However, it potentially also suggests a relative hesitancy of the evaluators to remove from the evaluation any heuristic. This potential hesitancy should be counteracted by the facilitator during the preparatory training and by active prompting to reflect on this during the debrief session.

## **C.8 Refining the Detailed Evaluation Procedures**

The observations from the workshop, in particular from the debrief sessions, as well as the findings outlined in previous sections, suggest that the evaluation protocol is effective. However, there are a number of refinements and guidelines within the detailed evaluation procedures that can offset some perceived deficiencies.

As discussed in section C.5, there was a recommendation from one education expert to remove the individual evaluations and debrief session in favour of a single group evaluation. After further analysis, this recommendation was not carried forward. Section C.6.1.3 reports correlation between the individual evaluation responses and the group response from the debrief session. However, this correlation is not strong enough to forgo the debrief session in favour of simply aggregating the individual evaluation responses. In short, the debrief session remains an integral part of the protocol, but with some suggestions for refinement. The first of which is to clearly differentiate that the debrief session is not a focus group and must be treated differently. This is discussed in more detail in the next section.

### **C.8.1 The Evaluation Debrief Session is not a Focus Group**

Evaluation debrief sessions, and in particular, the role of the facilitator, share much in common with focus groups; but with some notable differences. Ingrid Bens, an industry expert, author and founder of Facilitation Tutor, affirms that a facilitator is *“one who contributes structure and process to interactions so groups are able to function effectively and make high-quality decisions. A helper and enabler whose goal is to support others as they achieve exceptional performance.”* However, within the context of the debrief sessions, the primary objective is to build consensus amongst the evaluators. Specifically, in the areas of quantitative evaluation, and qualitative comment on pedagogical issues and improvement recommendations. In addition, the facilitator in a debrief session goes beyond being an enabler and the gatekeeper of group-process; the facilitator must be a content expert (knowledgeable of the syllabus, the heuristics, and the e-learning software) and therefore able and active in correcting misconceptions. The debrief session offers a final opportunity to correct mistakes by the evaluators or any misconceptions they may have, before they influence the final group response.

In both debrief sessions there were instances where individual evaluators had missed particular functionality in the e-learning software and therefore responded that particular heuristics were weakly or not supported. Such misconceptions are typically corrected by other evaluators in the group, but if not then they must be corrected by the facilitator to avoid corrupting the group result.

Ensuring the group's evaluation is aligned with the educational setting is crucial; this was a challenge in group-2 and to a lesser extent in group-1. If a group is evaluating based on a misconception of the learning context then they will evaluate unduly harshly or leniently, therefore the facilitator must step in to realign the group's understanding of the educational setting. This is to safeguard that the evaluation is based on an agreed, realistic and documented educational setting. This, in turn, affects reliability, since other groups doing a similar evaluation should evaluate based on the same education setting. In addition, it was also recommended to increase the emphasis of the education setting presentation (before the evaluation) and also include a short reminder presentation at the start of the debrief session.

On multiple occasions, evaluators commented that their individual response was mistaken because they had misunderstood the heuristic (and its criteria). This is often self-correcting since it comes out in discussion with the group. Much rarer will a significant portion of the group evaluate under a mistaken understanding of a heuristic. To pre-empt this, it is important that the evaluators have access to the evaluation criteria as they discuss a heuristic. Also that the facilitator is able to give clarification of a heuristic and its criteria, and that a facilitator actively engages if the evaluators are not evaluating a heuristic according to the stated criteria. As with group-2 heuristic 5.

The above three scenarios are particularly damaging when there are dominant figures within the evaluation group. It is already a part of the facilitator's role to balance such dominant figures, but it becomes critical if a dominant evaluator is working under a misconception and driving the group in the wrong direction.

The facilitator's role should be balanced and impartial; however, considering whether the evaluation is formative or summative in nature, the facilitator may wish to give some additional emphasis on either the qualitative or quantitative nature of the debrief session.

Giving a slight qualitative emphasis in formative assessments is useful since it motivates richer feedback on weak areas and recommendations on how to improve e-learning software, these can then be fed back into the design and development process. A slight quantitative emphasis in a summative assessment gives better alignment on the numeric measures of importance and level of support. The final quantitative measures of content quality, pedagogical quality and educational value can then be used to impartially evaluate multiple e-learning implementations and select accordingly.

As outlined previously, the primary purpose of the debrief session is to aggregate findings and build consensus, therefore it is the primary objective of the facilitator to promote and enable this.

It is unrealistic to expect that each evaluation will have a professional or highly experienced facilitator engaged; nevertheless, it is important that this role is actively assigned within the evaluation debrief

session. More, important that the person taking on the facilitation role is a dual expert with comprehensive knowledge of the education setting, and additional experience of both the heuristics and the e-learning software. To support this, additional facilitator guidelines were incorporated into the final e-learning evaluation protocol.

## **D E-LEARNING PEDAGOGY (FINAL)**

As discussed in section 4.2 of the thesis, the e-learning pedagogy was iteratively developed and refined through the three phases of this research study. Five versions of the e-learning pedagogy were developed and released. As a reference, this appendix contains the fifth and final version of the pedagogy: GCSE Computer Science E-Learning Pedagogy v1.8. In the interest of brevity and to avoid duplication, the lengthy bibliography section is not included in this version.

# **Pedagogical heuristics for the design and evaluation of e-learning software for high-school computing**

**by  
Peter Yiatrou**

A document deliverable submitted in partial fulfilment of the requirements for the  
degree of Doctor of Philosophy at the University of Central Lancashire



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# 1 DOCUMENT DETAILS

## 1.1 Document Version

Ver	Date	Phase	Document Name
0.7	04/02/2015	Phase 1	GCSE Computer Science E-Learning Pedagogy v0.7
1.2	01/12/2015	Phase 2-Cycle1	GCSE Computer Science E-Learning Pedagogy v1.2
1.5	05/06/2016	Phase 2-Cycle2	GCSE Computer Science E-Learning Pedagogy v1.5
1.7	04/10/2016	Phase 3	GCSE Computer Science E-Learning Pedagogy v1.7b (CLEAR)
1.8	02/10/2018	Final	GCSE Computer Science E-Learning Pedagogy v1.8

## 1.2 Document Distribution

Name	Role	Institution	Date

## 1.3 Copyright and Disclaimer

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## 1.4 Note on Referencing

This document is based on a significant literature review of relevant educational research. Where specific points are clearly attributable to an author, they are referenced accordingly (Refer to Chapter 12). However, in the interest of readability, underlying theories and concepts have not been referenced with academic rigour; this in no way implies that Peter Yiatrou is the source of these theories and concepts. Chapter 13 presents a bibliography of all the relevant educational and research literature.

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## 5 INTRODUCTION

### 5.1 Research Context

This [pedagogy](#) document is a key deliverable submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Central Lancashire.

This research study considers the increased focus that several developed countries<sup>3</sup> are taking towards high-school computer science. Additionally, it builds on the increasing integration of technology-enhanced learning into education, by supporting the use of e-learning software within a high-school environment. The research aims to support high-school computing with a comprehensive set of pedagogical [heuristics](#) to guide teachers in designing or evaluating e-learning software for use in their teaching.

In the context of this pedagogy, e-learning software is considered software that delivers content and instructional methods to facilitate learning, ideally in an engaging and interactive manner that promotes active learning. The e-learning software should cover a whole topic or portion of the curriculum, such as Algorithms, Programming, Data Representation, Networks, etc.; this differentiates e-learning software from the multitude of e-learning resources found on the web that can be used individually to support a small part of a curriculum.

Although e-learning software has the potential to offer significant learning benefits; there remains a concern that there is inconsistency in the quality of existing software, which often falls short, in particular in pedagogical design.

To support the increased use of e-learning software and simultaneously safeguard its pedagogical quality, this study synthesises well-established learning theories into a set of pedagogical heuristics that can be used by teachers or other educators in either the design or evaluation of e-learning software for computer science.

### 5.2 Audience and intended usage

The proposed heuristics and supplementary evaluation protocol are intended for use by teachers or instructional designers engaged in the design of new e-learning software or the expert evaluation of existing e-learning software. To qualify as an expert evaluator, it is necessary that the evaluator has instructional design experience or relevant teaching

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<sup>3</sup> Such countries include, but are not limited to: Australia, Belgium, France, India, Israel, Italy, New Zealand, Sweden, South Africa, Russia, the United Kingdom, and the United States.

experience. Where possible it is also preferred that the evaluator has domain knowledge of the subject area taught by the e-learning software.

The [learning theories](#) discussed in this pedagogy are not focused on any specific subject area; however, holistically the focus of the pedagogy is towards computer science. It follows that overall the pedagogy is designed to be more appropriate for computer science or other Science, Technology, Engineering and Mathematics (STEM) subjects, and therefore potentially less appropriate for other subject areas such as languages, arts, social studies and the humanities. These heuristics supplement existing literature on instructional design and extend existing e-learning heuristics since they focus more tightly and in-depth on pedagogy rather than usability. It is important to consider that:

1. The heuristics are not intended to instruct good pedagogy to teachers.
2. The heuristics offer guidance to teachers and instructional designers in the design or selection of e-learning software appropriate for high-school computer science education.
3. The heuristics are not intended to be implemented as a mandatory checklist.
4. The heuristics are intended to be used as a toolset in which the correct tools are selected by a teacher or instructional designer based on the specific learning material, intended audience and intended learning outcomes.
5. Although not explicitly considered in this pedagogy, usability is recognised to be critical to e-learning software and is a mandatory prerequisite to be considered in conjunction with pedagogical quality. Jakob Nielsen outlines one set of general usability heuristics that is well-established; this is included for reference in Appendix D.

## 6 LEARNING THEORY COVERAGE

With a focus on effective learning, it is natural that the described pedagogical heuristics are based on research and theories of how we learn best and enriched by the practical experience of teachers and education experts.

In broad terms, the learning process can be modelled across the three dimensions of Content, Incentive, and Environment (Refer to Figure 60)

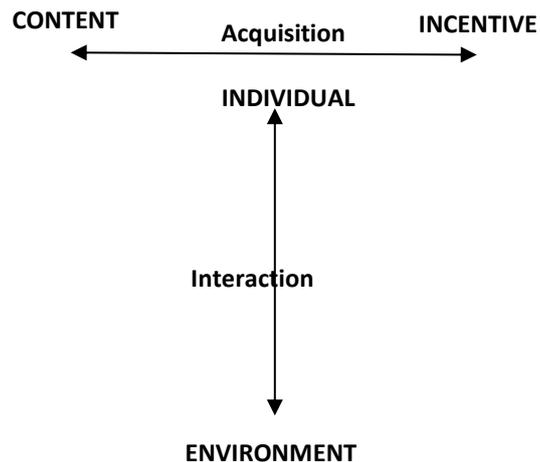


Figure 60: The fundamental processes of learning.

(Illeris 2009, p.9)

The first learning process is an external “*Interaction*” process between the learner and their social, cultural or material environment. This interaction with the external environment provides the initial stimulus for learning and allows the learner to integrate within communities and society in general. The interaction process involves action, communication and cooperation and takes varying forms such as perception, transmission, experience, imitation, activity and participation.

The external stimulus then feeds into an “*individual*” psychological process of elaboration and acquisition. This internal process focuses on managing the learning content and maintaining the incentive (motivation) to devote mental energy to learn. The content dimension focuses on identifying meaning and building understanding from the incoming information in such a way that it increases the learner’s overall abilities. However, such processes require significant cognitive effort, so there is a need for an incentive dimension that provides and directs the mental energy to support learning. This dimension aims for mental [equilibrium](#) and involves the learner’s motivation, volition and emotion.

As a theoretical foundation, this pedagogy synthesises the following well-established [learning theories](#) and one learning style theory. These theories were selected primarily due to their

maturity and the availability of research that discusses the theory, its effective implementation, and offers evidence of the theory's positive effect on learning and motivation. These theories are taken as a theoretical foundation for the heuristics and not prescribed in their extreme form. There is a concerted effort to find commonality and overlap between the theories in order to develop a cohesive set of pedagogical heuristics that can be used together with minimal conflict.

1. **Constructivism**, as pioneered by Piaget, either builds on or challenges current student knowledge to facilitate new learning. In essence, the learner actively constructs their own understanding (Brooks & Brooks 1999).
2. **Social Constructivism**, as pioneered by Vygotsky, defines the construction of new understanding as a **collaborative** (social) activity where a "*more knowledgeable other*" mediates the learning and provides the challenge to reach new learning (Pritchard 2009, p.117).
3. **Connectivism** is a more recent and radical theory which is rooted in the new connected digital era and WEB 2.0 technologies<sup>4</sup>. Learning is achieved by the interconnectedness of people/resources and is achieved ad-hoc, just-in-time learning (Bessenyei 2008).
4. **VARK Learning Style** theory focuses on sensory modalities and proposes that all students have different preferences in the best way they perceive new learning material. Neil Fleming's VARK Learning Style model (Fleming & Mills 1992), categorises the preferred learning style(s) and then offers appropriate learning strategies (Allen et al. 2011).
5. **Cognitive Load Theory** rationalises learning as the processing of inputs which are managed in short-term memory and coded for long-term recall. Since short-term memory is **limited**, this means efficient instructional practices that do not overload short-term memory are critical (Vogel-Walcutt et al. 2011; Clark & Mayer 2011).
6. **ARCS Theory of Motivation** – Motivation is widely recognised as a precursor to learning. Through years of research, John Keller has developed and tested a systematic process for analysing learner motivation and designing motivational techniques focused on the areas of Attention, Relevance, Confidence and Satisfaction (ARCS) (Keller 1987a; Keller 1987b; Keller 2008; Keller 2006).

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<sup>4</sup> Web 2.0 technologies such as blogs, forums, chats, wikis, newsgroups, e-portfolios, social networks, etc.

Also, in keeping with a focus on e-learning, technology, and high-school computer science, the pedagogy is similarly informed by research in the areas of e-learning best practice, collaborative learning, [gamification](#) and [computational thinking](#).

The learning theories, other research inputs, and the resultant heuristics are designed to provide comprehensive coverage of the two processes of external interaction and internal acquisition, and the three dimensions of content, incentive and environment. Please refer to [Figure 61](#) which maps the various theories to their primary area of educational influence.

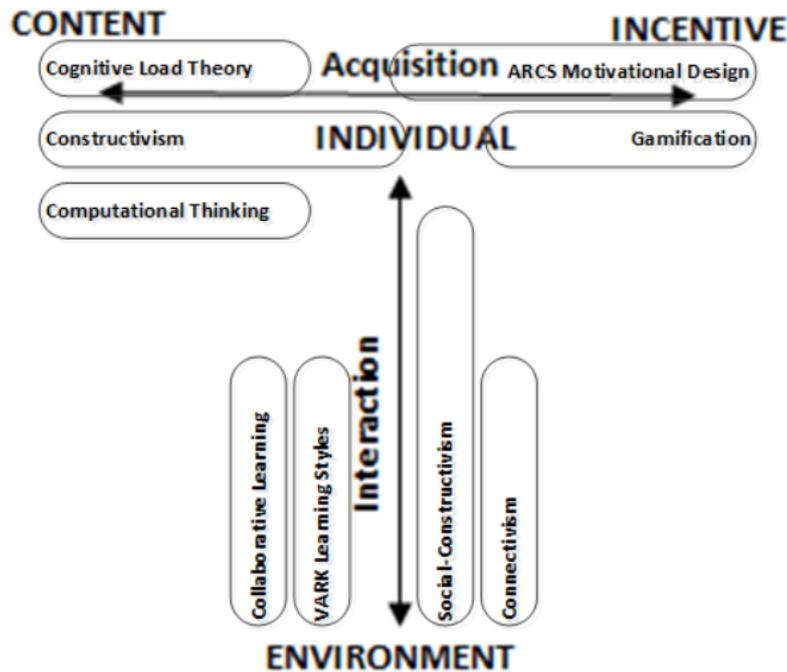


Figure 61: Mapping of learning theories to the three dimensions of learning.

For further information on each of the learning theories and the other inputs into the pedagogy, please refer to Appendix A.

## 6.1 Summary of Pedagogical Heuristics

[Table 10](#) outlines the e-learning heuristics recommended in this pedagogy; later sections describe in detail each heuristic with the following information:

- **ID:** A unique heuristic identification number.
- **Title:** The title of the heuristic.
- **Description:** A brief description that summarises the heuristic.
- **Learning Theory:** An indicator of whether the heuristic is derived from a particular learning theory.
- **Pedagogical Area:** An indicator of which area of instruction the heuristic relates to.

- **Design and Evaluation Criteria:** A set of criteria that can be used either as design guidelines to implement the heuristic in e-learning software or as evaluation guidelines to evaluate the adherence of existing e-learning software to the heuristic.
- **Education Benefits:** Outline of the potential benefits associated with the successful implementation of this heuristic.
- **Potential Challenges:** Outline of some of the potential challenges that could be faced when implementing the heuristic.
- **Related Heuristics:** Outline of other heuristics that interrelate with this heuristic either in positive support or potentially in contradiction.

The below table entries (refer to [Table 10](#)) link directly to the associated heuristics in electronic versions of the pedagogy.

ID	Heuristic Title	Page
<a href="#">1</a>	<p><b>Use authentic educational material, examples and activities.</b> Authentic learning represents learning material in a manner that focuses on the context of when the knowledge and skills will be used. It allows the learner a closer tie to reality and a better understanding of the relevancy of the material and its true value. This, in turn, leads learners to take greater ownership of their learning, a deeper understanding and increased knowledge transfer to the real world.</p>	119
<a href="#">1.1</a>	<p><b>Ensure the currency of learning material.</b> The nature of information is that it is continually changing; meaning its accuracy and validity must be re-evaluated, which in turn leads to a re-evaluation of existing knowledge and the possibility to learn more. Learning material in the e-learning software and the <a href="#">Collaborative Learning Environment (CLE)</a> must be kept up-to-date; also, students should be given access to a learning network of other current learning resources and the skills to evaluate the validity of those learning resources.</p>	121
<a href="#">2</a>	<p><b>Prompt reflective practice to support learning.</b> <a href="#">Reflective practice</a> is the careful contemplation of one’s own thinking processes, actions and beliefs that in turn support further learning; it is an integral part of the constructivist knowledge building process. Learners typically do not reflect on their learning unless guided to do so; therefore, the e-learning software and CLE should provide reflective prompts and associated activities. These typically take the form of questions or discussions that stimulate the imagination, theory creation, further thinking, further questions or meta-cognitive thinking.</p>	122

ID	Heuristic Title	Page
<a href="#">3</a>	<p><b>Make expert and learner thinking processes explicit.</b></p> <p>Students often learn something but may not be clear on the rationale behind it, when to do it, how to gauge progress or whether the approach is working. The e-learning software and teachers (via the CLE) should make invisible mental processes explicit for the learner to understand and thereby implement. Likewise, learners must undertake activities to clarify and reflect on their underlying thinking and the rationale for their actions in resolving a problem.</p>	124
<a href="#">4</a>	<p><b>Use problem-based learning (PBL) to facilitate learning.</b></p> <p>Problem-based learning, in contrast to <a href="#">part-task</a> instruction, focuses on the bigger picture and begins with an authentic problem or work assignment which drives the learning process in trying to solve the problem. Working on the problem takes the form of a guided discovery that integrates into the process the necessary knowledge and skills to solve the problem and arguably results in a richer more challenging learning experience.</p>	126
<a href="#">4.1</a>	<p><b>Use worked-examples to support problem-based learning.</b></p> <p>A worked-example is a step-by-step demonstration of how to perform a task or solve a problem and is one of the most effective methods to support learning; in particular the <a href="#">far transfer</a> of learning and building new cognitive skills. In this context, the examples are non-trivial and involve <a href="#">higher order thinking</a> to solve problems where there are potentially multiple appropriate solutions.</p>	129
<a href="#">5</a>	<p><b>Integrate learning into long-term memory by using authentic examples, and non-trivial practice and problems.</b></p> <p>To facilitate <a href="#">deep learning</a>, students must integrate new learning material into existing <a href="#">schemas</a> in their long-term memory. This allows learning to move beyond memorisation and fact recall and enables the more flexible application of knowledge and skills to scenarios not explicitly covered in the learning material.</p>	132
<a href="#">6</a>	<p><b>Support problem-solving through computational thinking.</b></p> <p>Computational thinking is a way of thinking based on computer science concepts in order to reformulate and solve problems. There currently is no authoritative definition of what these computer science thought processes are, but one stable definition involves six concepts: a thought process, abstraction, decomposition, algorithmic design, evaluation, and generalisation. Computational thinking is both an important computer science topic that</p>	134

ID	Heuristic Title	Page
	arguably deserves its own pedagogical heuristics, but also a way of thinking that influences the heuristics for problem-solving.	
<a href="#">6.1</a>	<p><b>Build a foundation for computational thinking.</b></p> <p>Before students can employ computational thinking; they must first have a clear foundation on what the elements of computational thinking are, be presented with real-world examples to broaden their knowledge base, and become comfortable with the use of computational vocabulary to describe problems and solutions. This acts as scaffolding or pre-training before students start using computational thinking techniques.</p>	135
<a href="#">6.2</a>	<p><b>Exemplify computational thinking in problem-solving activities.</b></p> <p>Once a stable foundation of computational thinking concepts and terminology is established, we must exemplify the ethos, approaches and concepts used in computational thinking through worked-examples and problem-solving activities that learners can actively engage in.</p>	136
<a href="#">7</a>	<p><b>Distribute well-designed practice activities across the lesson to support learning.</b></p> <p>Practical activities should be distributed throughout the e-learning software to support and solidify learning, rather than as an assessment of learning. The design of these activities should be for the student to apply their learning and promote further thinking, instead of shallow activities such as recognising or reiterating facts.</p>	138
<a href="#">7.1</a>	<p><b>Provide explanatory feedback to practice activities to promote learning.</b></p> <p>Explanatory feedback on practice activities is a further opportunity to promote learning, instead of focusing solely on assessment. In comparison to other factors influencing learning, integrating explanatory feedback into the learning process is one of the most effective.</p>	140
<a href="#">8</a>	<p><b>Provide scaffolding to advance learning progress.</b></p> <p>Scaffolding is the process by which a teacher or other guiding figure (including the e-learning software and even more knowledgeable students) provide additional instructional assistance, guidance, or prompting that supports a student's learning process so they can accomplish an activity that is generally out of their reach.</p>	142

ID	Heuristic Title	Page
<a href="#">9</a>	<p><b>Use social-interaction to increase learning and promote higher-order thinking.</b></p> <p>Social constructivism builds upon <a href="#">cooperative</a> and <a href="#">collaborative</a> learning, and reflective learning practices to emphasise the importance of social interactions in shaping the learner’s knowledge construction. It supports learners in reaching a higher level of learning than what can be achieved individually. Also, the social interaction of individuals can often lead to learning that is greater than the sum of the individuals, ultimately resulting in a shared understanding inherently derived from the learning community.</p>	144
<a href="#">10</a>	<p><b>Engage learners in a challenge; target learning towards the zone of proximal development (ZPD).</b></p> <p>The Zone of Proximal Development (ZPD) is a theoretical space of understanding which is just above the level of understanding of a given individual and which can only be reached with support. It is the necessity of this support by others that explains the importance of social interaction for learning development. It should be noted that the role of the more knowledgeable other is not a role reserved only for the teacher; a more capable peer often takes it.</p>	146
<a href="#">11</a>	<p><b>Use collaborative learning activities.</b></p> <p>The integration and construction of knowledge in schemas (in long-term memory) happens on an individual level; however, it is evident that other people affect the learning process and that arguably learning most naturally occurs, not in isolation, but when students work together. Collaborative learning capitalizes on other people’s knowledge, skills and resources; allowing learners to monitor each other’s work, share information, summarise points, verify and test their knowledge, and debate their opinions.</p>	148
<a href="#">11.1</a>	<p><b>Support collaborative and situated learning via mobile devices.</b></p> <p>Arguably, we are currently living through a paradigm shift from education in formal settings, towards education that extends beyond the classroom to become more situated, personal, collaborative and informal. This paradigm shift is supported by the explosion of mobile devices, their significantly enhanced capabilities, pervasive wireless networks and cloud computing that enable communication, collaboration and sharing of information resources almost anywhere.</p>	151

ID	Heuristic Title	Page
<a href="#">12</a>	<p><b>Develop and nurture networks to support learning.</b></p> <p>Connectivism proposes that knowledge lies in a diversity of opinions and that this knowledge resides in a network of interconnected entities called nodes. These nodes can be almost anything with learning value, such as individuals, groups, systems, fields, ideas, or communities, but for the most part the focus lies on humans and digital resources. Although connectivism is not explicitly dependent on the Internet, the rapid growth of the web has given significant impetus to connectivism as a learning theory touted for the digital age. In its most powerful form, the connectivist network can be developed into a learning community that clusters together similar areas of interest and facilitates the sharing of knowledge, dialogue and other interactions that support learning.</p>	153
<a href="#">13</a>	<p><b>Use constructivist approaches to increase intrinsic motivation in the learner.</b></p> <p><a href="#">Intrinsic</a> motivation stems from interest or enjoyment in the learning or the activity itself, and originates within the individual rather than relying on external incentives. Motivation is vital in giving the learner incentive to devote the mental energy to learn. Several constructivist principles such as whole-task and problem-based learning, authentic learning, active learning, <a href="#">mindful activity</a>, etc. are shown to be intrinsically motivational and therefore supportive of the learning process.</p>	156
<a href="#">14</a>	<p><b>Use the concepts of Attention, Relevance, Confidence and Satisfaction (ARCS) to attain and sustain learner motivation.</b></p> <p>Irrespective of the effectiveness of the learning material, without motivation, students are hampered from learning, and while motivation cannot be directly controlled, it can be positively influenced. According to the ARCS model, in order to predictably improve motivation and performance, the instructional material and environment should capture the learners' attention, ensure relevance to the learner, build learner confidence and ensure learner satisfaction.</p>	158
<a href="#">14.1</a>	<p><b>Use "Attention" grabbing strategies to increase learner motivation.</b></p> <p>The first step in increasing learner motivation is to capture their attention and then employ strategies to sustain their attention throughout the learning process. This involves initial inquiry arousal, stimulating a deeper level of curiosity and then sustaining attention via varied instructional techniques.</p>	159

ID	Heuristic Title	Page
<a href="#">14.2</a>	<p><b>Explain the “Relevance” of the learning material to increase motivation.</b></p> <p>To ensure that motivation is maintained the learner must perceive the learning material has a personal relevance to them; there must be a <i>“connection between the instructional environment, which includes content, teaching strategies, and social organization, and the learner’s goals, learning styles, and past experiences”</i> (Keller 2008, p.177).</p>	161
<a href="#">14.3</a>	<p><b>Build “Confidence” to increase learner motivation.</b></p> <p>Building learners’ confidence in their ability to learn also increases their motivation to learn; any learned helplessness or fear of the topic, skill or environment that hinders learning should be addressed and replaced by an expectation of success. The positive expectancy for success should then be followed promptly by actual success that the learners can clearly attribute to their own abilities and efforts.</p>	163
<a href="#">14.4</a>	<p><b>Build “Satisfaction” to increase learner motivation.</b></p> <p>Once motivation is inspired in the learner, it needs to be maintained by providing the learner with a sense of satisfaction with the process and/or results of the learning experience. This is achieved by a combination of intrinsic methods, <a href="#">extrinsic</a> reinforcement and a sense of fairness in the learning results.</p>	165
<a href="#">15</a>	<p><b>Use gamification to increase motivation and learning performance.</b></p> <p>In the context of e-learning, <a href="#">gamification</a> is the use of game design elements within e-learning software to increase the pleasure, fun, and motivation in the learning process and to encourage positive learning behaviour. Game design elements must be tightly integrated with existing intrinsically motivational aspects of the software. Suggested game design elements include: points, leader-boards, achievements/badges, levels, rewards, progression, challenge, storytelling, clear goals, rapid feedback, explanatory feedback, freedom to fail, etc.</p>	166
<a href="#">15.1</a>	<p><b>Integrate gamification elements tightly within existing learning processes.</b></p> <p>Many aspects of good game design correlate with existing pedagogical practices; therefore, they should already exist within the instructional design of the e-learning software. These should not be reinvented for gamification purposes; instead, gamification elements should simply integrate with the existing pedagogical elements. These pedagogical elements include:</p>	168

ID	Heuristic Title	Page
	storytelling, progressive challenge, intrinsically motivational activities, rapid explanatory feedback, tutorials on how to use (play), and social interaction.	
<a href="#">15.2</a>	<p><b>Build extrinsic gamification elements on top of existing learning processes.</b></p> <p>Certain gamification elements are not part of established pedagogical approaches; they attempt to leverage people’s love of competition and reward to encourage desired learning behaviour. They reflect learner progress and attempt to motivate desired learning behaviour through extrinsic rewards such as Points, Leader-boards, Achievements/Badges and Levels. Since these gaming elements are not inherently part of existing pedagogical practices, they need to be built on top; however, they should only be used if there is an existing foundation in heuristic 15.1.</p>	171
<a href="#">16</a>	<p><b>Use multi-modal learning approaches.</b></p> <p>Students are not restricted to only one of the modal preferences (visual, aural, read-write, or kinaesthetic). It is typical for students to exhibit a preference for one particular mode, and a relative weakness or strength in some other modes. However, it must be recognised that even the relatively weaker modes cannot be ignored; even if a student has a strong preference on a particular modality, they should still be exposed to diverse learning experiences and encouraged to develop into more versatile learners. The e-learning software should accommodate the four modalities by providing a variety of different learning options that consider the different learning styles. By combining a mixture of approaches, the students are given the possibility to choose the instructional style that best fits their own individual learning style(s).</p>	173
<a href="#">16.1</a>	<p><b>Support visual modal preference.</b></p> <p>Visual learners prefer graphical and symbolic ways of representing information. They have good visual recall and prefer information to be presented visually, in the form of diagrams, graphs, maps, posters, displays, etc. In addition, where learning material is complex, includes invisible or difficult to see phenomenon, or has difficult concepts or process steps, then special attention must be given to visualization tools that help learners to construct appropriate mental images and visualize activities.</p>	175

ID	Heuristic Title	Page
<a href="#">16.2</a>	<p><b>Support aural modal preference.</b></p> <p>Auditory learners prefer to learn from listening. They have good auditory memory and benefit from lectures, tutorials, discussions with other students and faculty, interviewing, hearing stories, audio tapes, etc.</p>	177
<a href="#">16.3</a>	<p><b>Support read-write modal preference.</b></p> <p>Read-write learners prefer to learn through information displayed as words; they benefit from lecture notes, note taking, journals, lists, definitions, textbooks, etc.</p>	178
<a href="#">16.4</a>	<p><b>Support kinaesthetic modal preference.</b></p> <p>Kinaesthetic learners prefer learning that connects to their experience and reality. They are more adept at recalling events and associated feelings or physical experiences from memory. This experience can be derived through physical activity such as field trips, manipulating objects and other practical first-hand experience. However, it can also be derived through simulation and the presentation of information strongly tied to experience and reality. Hence, Kinaesthetic learning can be multi-modal since the information describing experience and reality can be presented in a visual, aural or read-write form.</p>	180
<a href="#">17</a>	<p><b>Integrate words and graphics together, instead of words alone.</b></p> <p>An important part of <a href="#">active processing</a> is to construct visual and text representations of learning material and connect them mentally. The e-learning software should, therefore, include both words (audio or screen text) and graphics (static illustrations, animations or videos) to support learners in developing their mental models. The visual elements should not be treated as an afterthought after the text has been written; instead, multimedia lessons should contain words and corresponding visuals that work together to explain the learning content.</p>	181
<a href="#">17.1</a>	<p><b>Apply contiguity by aligning words (audio or screen text) with corresponding graphics.</b></p> <p>It is important to avoid learning material that requires learners to split their attention between, and mentally integrate, multiple sources of information. The process of integrating distinct sources of information creates an unnecessary cognitive load that can be avoided by aligning and integrating Words (audio or screen text) in close proximity (i.e. contiguous) to corresponding graphics.</p>	183

ID	Heuristic Title	Page
<a href="#">17.2</a>	<p><b>Representing words as audio, on-screen text or both</b></p> <p>When words are accompanying visual elements, and both require the learner’s simultaneous attention, it is typically better to present the words as audio instead of on-screen text. This avoids cognitive overload by balancing the learning material across two separate <a href="#">cognitive channels</a> - words in the auditory channel and graphics in the visual channel. Furthermore, it is typically recommended to not duplicate words via audio and screen text. This avoids situations where the learner focuses too much on-screen text to the detriment of the graphics or potentially focusing on the screen text and narration and comparing whether they are equivalent. However, exceptions to these guidelines do apply.</p>	185
<a href="#">18</a>	<p><b>Avoid adding learning content that does not directly support your instructional goal.</b></p> <p>Learning content should directly support the instructional goal. There is a strong temptation to add extra material in e-learning that will grab the attention of students and keep them interested and engaged. This can lead to interesting but unnecessary learning material, the use of overly dramatic stories and examples, and gratuitous use of text, audio, visual and multimedia elements, which in turn can actually harm the learning process. It is important to note this is one of the most commonly violated principles, but is relatively easy to implement and can give a significant learning improvement.</p>	187
<a href="#">19</a>	<p><b>Optimise essential processing by segmenting learning material and providing pre-training.</b></p> <p>In the cognitive learning theory, essential processing reflects the learning processes used by the student to understand the core learning material. It is fundamental to the learning process, but can be significantly impacted by the inherent complexity of the material. Therefore, to get better learning results, it is vital that the complexity of the learning material is effectively managed. Two approaches are suggested to manage this complexity: segmenting breaks a lesson into manageable segments that do not overload the student’s cognitive processes, and pre-training provides foundation information that gives names and characteristics of key concepts that can be built upon and used in the main learning segments.</p>	189

ID	Heuristic Title	Page
<a href="#">20</a>	<p><b>Use a conversational style in screen text and audio narration.</b></p> <p>It is recommended that the e-learning software should use a conversational style (using first- and second-person and active language) in both screen text and audio narration and should avoid the use of formal and passive voice. This helps the learner engage with the e-learning software in a manner closer to a social conversational partner.</p>	191
<a href="#">21</a>	<p><b>Provide restricted navigational control in the e-learning software.</b></p> <p>Learner control is implemented by navigational features that allow the learner to choose the path they take through the e-learning software, by selecting the topics and instructional elements they prefer, and the pace at which they undertake learning. This pedagogy recommends a restricted level of navigational control and focuses more towards program control. However, the learner must be given freedom in a number of critical areas; these are the pace of learning, the ability to revisit content that has already been covered and to allow learners as much personal control (as possible) over their actual learning experience.</p>	192
<a href="#">21.1</a>	<p><b>Provide consistent navigational elements and signposts for learning.</b></p> <p>The e-learning software should provide a clear and consistent Graphical User Interface (GUI) that places a minimal cognitive demand on the learner and intuitively supports learning. One crucial part of this is to provide clear navigational elements and visual cues (signposts) of the learning material that emphasises recognition rather than recall.</p>	194

Table 10: Summary of pedagogical heuristics.

## 7 RELATIONSHIPS BETWEEN HEURISTICS

As discussed previously, the heuristics are intended to be used as a toolset in which the correct tools are selected and used together to achieve the intended learning outcomes. It is therefore important to understand how the heuristics interrelate and influence each other. [Figure 62](#) provides a high-level interrelationship map showing some of the key relationships between pedagogical areas and heuristics. A more detailed analysis is provided in section 11 in the heuristic interrelationship matrix. Both represent the interrelationships between heuristics as documented in the Related Heuristics section of each heuristic and offer a visualisation to teachers and instructional designers on how the heuristics can positively support or potentially counteract each other. The value of the interrelationship map and matrix are in stimulating reflection on how the choice of heuristics may affect other heuristics. However, ultimately, in any given e-learning implementation it cannot be guaranteed that these relationships will materialise or that other relationships will not emerge.

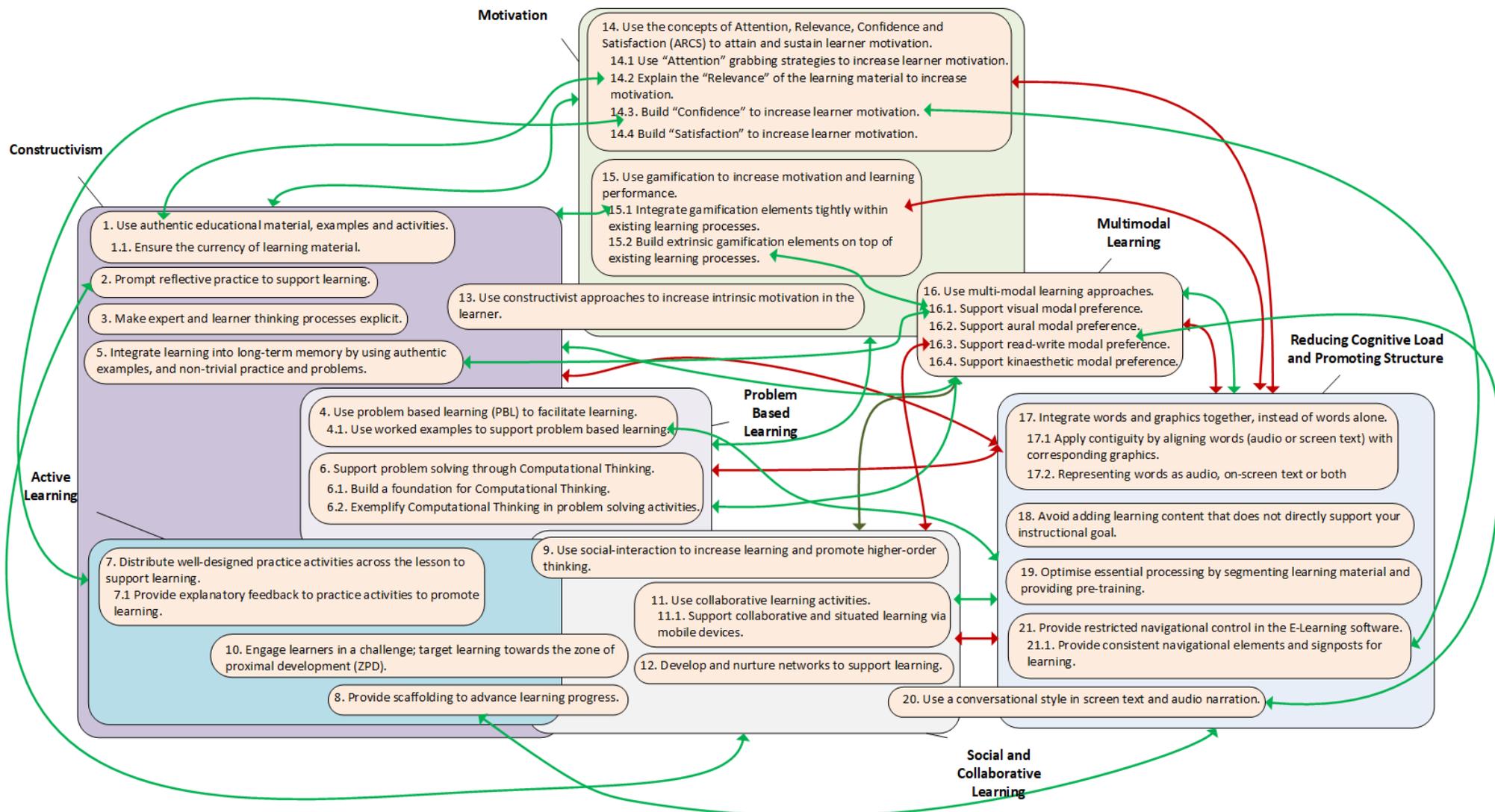


Figure 62: Heuristics interrelationship map.

**Directions for Use**

Heuristics that are highly related are grouped into boxes reflecting a pedagogical area. Boxes that are enclosed or overlap reflect a strong positive relationship. Green relationship lines reflect a positive relationship between pedagogical areas or specific heuristics. Red relationship lines reflect a counteractive relationship between pedagogical areas or specific heuristics

## 8 EDUCATIONAL BENEFITS

The educational benefits matrix provided in Table 11 indicates the learning benefits that can potentially be achieved by the successful implementation of each heuristic. The educational benefits are categorised into five main areas:

1. **Learning Performance (Surface Learning):** Learning performance is an immediate measure of the students' ability to recall learning material and successfully pass assessments closely linked to that learning material. In the context of this research, this relates to the students' ability to pass GCSE Computing assessments and exams.
2. **Deep Learning:** As opposed to surface learning, in which learning material is typically passively memorised with a primary aim of passing assessments; deep learning is learning where there is a vigorous interaction with the learning material to truly understand it and integrate it with previous experience and knowledge. Meaning it is integrated into existing mental schemas in the learner's long-term memory.
3. **Far Transfer / Higher Order Thinking:** Far Transfer is the application of skills and knowledge learned in one situation to a different situation. It builds upon deep learning and requires learners to adjust the underlying principles they have learnt, for use in a new scenario or new problem. It requires higher order thinking, which regarding Blooms revised taxonomy (Krathwohl 2002) includes Analysing, Evaluating and Creating.
4. **Motivation:** Motivation is a theoretical construct used to explain the reason(s) one has for acting or behaving in a particular way and relates to the general desire or willingness of someone to do something. In the context of this research, it focuses on the incentive (motivation) to devote mental energy to learn.
5. **Cognitive Load:** At any given time, humans can actively process only limited information; material that exceeds this threshold may enter working memory but will not be processed and encoded into long-term memory. It is therefore vital that the cognitive processes that organise incoming information into logical structures and integrate it with existing knowledge are supported by optimising the learning material to reduce cognitive load.

The educational benefits matrix is based on a substantial review of relevant research as documented in the Educational Benefits section of each heuristic. However, ultimately, this review is bounded, and the implementation of a heuristic does not guarantee that the educational benefit will be realised and does not preclude that other educational benefits will be realised. This matrix is offered as high-level visual guidance to teachers and instructional designers on what heuristics can be focused on when targeting certain educational benefits.

LEGEND						
		Learning Performance	Deep Learning	Far Transfer / Higher Order Thinking	Increased Motivation	Reduce Cognitive Load
ID	Heuristic Title					
1	Use authentic educational material, examples and activities.	Strong	Strong	Strong	Strong	Counteracts
1.1	Ensure the currency of learning material.	Moderate	Moderate	Moderate	Strong	Counteracts
2	Prompt reflective practice to support learning.	Strong	Strong	Strong	Strong	No
3	Make expert and learner thinking processes explicit.	Strong	Strong	Strong	Strong	Counteracts
4	Use problem based learning (PBL) to facilitate learning.	Strong	Strong	Strong	Strong	Counteracts
4.1	Use worked examples to support problem based learning.	Strong	Strong	Strong	Strong	Counteracts
5	Integrate learning into long-term memory by using authentic examples, and non-trivial practice and problems.	Strong	Strong	Strong	Strong	Counteracts
6	Support problem solving through Computational Thinking.	Moderate	Strong	Strong	Moderate	No
6.1	Build a foundation for Computational Thinking.	Moderate	Strong	Strong	No	Strong
6.2	Exemplify Computational Thinking in problem solving activities.	Moderate	Strong	Strong	Strong	Counteracts
7	Distribute well-designed practice activities across the lesson to support learning.	Strong	Strong	Moderate	Strong	No
7.1	Provide explanatory feedback to practice activities to promote learning.	Strong	Strong	Moderate	Strong	Moderate
8	Provide scaffolding to advance learning progress.	Strong	Strong	Moderate	Strong	Strong
9	Use social-interaction to increase learning and promote higher-order thinking.	Moderate	Strong	Moderate	Strong	No
10	Engage learners in a challenge; target learning towards the zone of proximal development (ZPD).	Strong	Strong	Moderate	No	No
11	Use collaborative learning activities.	Strong	Strong	Moderate	Strong	No
11.1	Support collaborative and situated learning via mobile devices.	Moderate	Moderate	Moderate	Strong	Strong
12	Develop and nurture networks to support learning.	Strong	Strong	Strong	Strong	Counteracts
13	Use constructivist approaches to increase intrinsic motivation in the learner.	Strong	Strong	Strong	Strong	Counteracts
14	Use the concepts of Attention, Relevance, Confidence and Satisfaction (ARCS) to attain and sustain learner motivation.	Strong	Strong	Moderate	Strong	Counteracts
14.1	Use "Attention" grabbing strategies to increase learner motivation.	Strong	Moderate	Moderate	Strong	Counteracts
14.2	Explain the "Relevance" of the learning material to increase motivation.	Strong	Strong	Moderate	Strong	Counteracts
14.3	Build "Confidence" to increase learner motivation.	Strong	Strong	Moderate	Strong	No
14.4	Build "Satisfaction" to increase learner motivation.	Strong	Strong	Strong	Strong	Counteracts
15	Use gamification to increase motivation and learning performance.	Strong	Moderate	Moderate	Strong	Counteracts
15.1	Integrate gamification elements tightly within existing learning processes.	Strong	Strong	Strong	Strong	Counteracts
15.2	Build extrinsic gamification elements on top of existing learning processes.	Strong	No	No	Strong	No
16	Use multi-modal learning approaches.	Strong	Strong	Moderate	Strong	Counteracts
16.1	Support visual modal preference.	Strong	Strong	Moderate	Strong	Strong
16.2	Support aural modal preference.	Strong	Moderate	Moderate	Strong	Counteracts
16.3	Support read-write modal preference.	Strong	Strong	Moderate	Strong	Counteracts
16.4	Support kinaesthetic modal preference.	Strong	Strong	Moderate	Strong	Counteracts
17	Integrate words and graphics together, instead of words alone.	Strong	Strong	Moderate	Moderate	Strong
17.1	Apply contiguity by aligning words (audio or screen text) with corresponding graphics.	Strong	Strong	Moderate	Moderate	Strong
17.2	Representing words as audio, on-screen text or both	Strong	Strong	Moderate	Moderate	Strong
18	Avoid adding learning content that does not directly support your instructional goal.	Strong	Counteracts	Counteracts	Counteracts	Strong
19	Optimise essential processing by segmenting learning material and providing pre-training.	Strong	Moderate	Counteracts	No	Strong
20	Use a conversational style in screen text and audio narration.	Strong	Moderate	Moderate	Strong	Moderate
21	Provide restricted navigational control in the E-Learning software.	Strong	Moderate	Moderate	No	Strong
21.1	Provide consistent navigational elements and signposts for learning.	Strong	Moderate	Moderate	No	Strong

Table 11: Educational benefits matrix

## 9 HEURISTIC DESCRIPTIONS

ID	Heuristic Title:		
1	Use authentic educational material, examples and activities.		
<b>Learning Theory:</b>	Constructivism	<b>Pedagogical Area:</b>	Authenticity
<b>Description:</b>			
<p>Authentic learning represents learning material in a manner that focuses on the context of when the knowledge and skills will be used. It allows the learner a closer tie to reality and a better understanding of the relevancy of the material and its true value. This, in turn, leads learners to take greater ownership of their learning, a deeper understanding and increased knowledge transfer to the real world.</p>			
<b>Design and Evaluation Criteria:</b>			
<p>The learning material and activities in the e-learning software and associated CLE should reflect a meaningful subset of the following characteristics of authenticity:</p> <ol style="list-style-type: none"> <li><b>1. Provide contextual authenticity by:</b> <ol style="list-style-type: none"> <li>a. Exploring the real-world dimensions of a task,</li> <li>b. Providing realistic background information that surrounds the learning or problem,</li> <li>c. Simulating real-life complexities and occurrences, or</li> <li>d. Using practices and tools used by experts in the field under study.</li> </ol> </li> <li><b>2. Provide cognitive authenticity by engaging the learner in activities which present the same type of intellectual challenges as those in the real-world.</b></li> <li><b>3. Provide activities that are intrinsically motivating, that learners are encouraged to solve.</b></li> <li><b>4. Provide learning and activities that are personally relevant or interesting to the learner.</b></li> <li><b>5. Provide learning and activities that are not artificially constrained.</b></li> <li><b>6. Provide the technical affordance for teachers and instructional designers to easily change text and visual learning material to be more authentic and personalised to their students.</b></li> </ol>			
<b>Educational Benefits:</b>			
<p>The use of authentic educational material, examples and activities leads to the following education benefits:</p>			

1. Learners more successfully [assimilate](#) / [accommodate](#) the learning into their own [mental models](#) (schemas).
2. There is an increased likelihood that learners will take ownership of their learning or the resolution of a problem activity.
3. Learners more effectively grasp the meaning and value of the learning material and the context in which the knowledge or skills can be used in the real world.
4. Learners are more motivated by authentic or personally relevant learning material.
5. Authentic learning enables deeper learning and improved far transfer.

#### Potential Challenges:

It is important that authentic learning ties back to reality; but it should not model reality in an ultra-realistic manner that overwhelms the learner or constrains the learning to a narrow context. Instead, it is better to provide more focus to cognitive authenticity.

Although, authentic learning most intuitively fits into whole-task instruction; special care should still be given to examples and problems within part-task instruction to maintain a reasonable level of authenticity where possible.

#### Related Heuristics:

Authentic learning offers strong support in the following areas:

- Ensuring the currency of learning material (Heuristic 1.1).
- Reflective practice and making expert and learner thinking processes explicit (Heuristics 2, 3).
- Integrating learning into long-term memory (Heuristic 5).
- Problem-based learning and computational thinking (Heuristics 4, 4.1, 6, 6.1, 6.2).
- Practice activities and kinaesthetic learning (Heuristics 7, 16.4)
- Social and collaborative learning, situated learning through mobile devices, and networked learning (Heuristic 9, 11, 11.1, 12).
- Learner motivation and gamification (Heuristics 13, 14, 14.2, 14.4, 15, 15.1).

However, it is important to consider that authentic learning can increase cognitive load and conflict with heuristics 18 and 19, relating to the optimisation of essential processing and focusing only on learning material that directly supports learning objectives.

<b>ID</b>	<b>Heuristic Title:</b>		
1.1	Ensure the currency of learning material.		
<b>Learning Theory:</b>	Connectivism	<b>Pedagogical Area:</b>	Currency Authenticity
<b>Description:</b>			
<p>The nature of information is that it is continually changing; meaning its accuracy and validity must be re-evaluated, which in turn leads to a re-evaluation of existing knowledge and the possibility to learn more. Learning material in the e-learning software and the CLE must be kept up-to-date; also, students should be given access to a learning network of other current learning resources and the skills to evaluate the validity of those learning resources.</p>			
<b>Design and Evaluation Criteria:</b>			
<p>The process by which students refresh their knowledge is a learning process that cannot be automated, but can be supported by the e-learning software and CLE in the following ways:</p> <ol style="list-style-type: none"> <li><b>1. Learning material and activities are up-to-date and easily editable so they can be kept current.</b> The technology and underlying design of e-learning software and CLE activities should support the easy editing of learning material to ensure it is kept up-to-date.</li> <li><b>2. The e-learning software should act as a focal point that recommends other learning resources (nodes on the learning network) that are current.</b> In accordance with moderate connectivist approaches, the e-learning software should act as a focal point that recommends other learning resources through web links. These links should, in turn, be editable by the teachers using the software.</li> <li><b>3. Use technology to keep up-to-date.</b> Push and pull technologies can help support the process of refreshing ones knowledge by delivering changing learning material. One such technology is Rich Site Summary (RSS) web feeds, which deliver regularly changing web content to whoever wants to subscribe.</li> <li><b>4. Other people can provide up-to-date information.</b> An important source of current information and new perspectives are other learners and knowledgeable others that can be contacted via the CLE.</li> </ol>			
<b>Educational Benefits:</b>			
<p>Learning is no longer constrained by one book or one perspective that may become outdated; instead, through connectivism, the learner has access to a variety of existing nodes that are kept up to date, or replaced by new nodes and new contributors. This gives the learner the opportunity to experience learning that is refreshed and kept up to date.</p>			

<b>Potential Challenges:</b>	
<p>To some extent, this heuristic is out of step with current educational practice in which there is a single set syllabus and set textbooks that are to be examined. It is clear that in the current educational climate this cannot be abandoned. Nonetheless, there remains room for students to search and explore new information that may be more current.</p> <p>This heuristic requires critical and <a href="#">metacognitive</a> skills that students may not inherently have; therefore, requiring additional support and instruction from teachers. Please refer to Appendix B.1 for a brief discussion of the additional instructional support needed.</p> <p>One technology used to support this heuristic is RSS feeds; however, at this time (December 2017), there seems to be a limited set of RSS feeds in the educational arena.</p>	
<b>Related Heuristics:</b>	<p>The currency of learning material offers strong support in the following areas:</p> <ul style="list-style-type: none"> <li>• Ensuring the authenticity of learning material (Heuristic 1)</li> <li>• Guided discovery within PBL approaches (Heuristic 4)</li> <li>• Social, collaborative and situated learning (Heuristic 9, 11, 11.1)</li> <li>• Connectivist principles of learning networks (Heuristics 12)</li> <li>• Intrinsic, ARCS and gamification based motivational approaches (Heuristic 13, 14,14.2, 14.4, 15, 15.1)</li> </ul> <p>However, it is important to consider that a focus on the currency of learning material can increase cognitive load and conflict with heuristics 18 and 19, relating to the optimisation of essential processing and focusing only on learning material that directly supports the learning objectives.</p>

<b>ID</b>	<b>Heuristic Title:</b>		
2	Prompt reflective practice to support learning.		
<b>Learning Theory:</b>	Constructivism Social-Constructivism	<b>Pedagogical Area:</b>	Reflection
<b>Description:</b>			
<p>Reflective practice is the careful contemplation of one’s own thinking processes, actions and beliefs that in turn support further learning; it is an integral part of the constructivist knowledge building process. Learners typically do not reflect on their learning unless guided to do so, therefore, the e-learning software and CLE should provide reflective prompts and associated activities. These typically take the form of questions or discussions that stimulate</p>			

the imagination, theory creation, further thinking, further questions or meta-cognitive thinking.

#### Design and Evaluation Criteria:

A meaningful subset of the following reflection prompts and activities should be included in the e-learning software and associated collaborative learning activities:

- 1. Provide reflective prompts within the learning material,** such as:
  - ask the learners to reflect on what learning strategies they used,
  - ask the learners to explain why they made a particular response,
  - ask the learners to confirm or state how certain they are in a response, or
  - ask the learners to discuss, explain and justify their opinion with another learner.Appendix C contains a number of example questions (authored by Lisa Chesser) that can be adapted and used to promote learning reflection.
- 2. Include reflective practice at key points when students are challenged in accommodating new learning.** Reflective practice is most valuable when learners are perplexed in trying to accommodate new learning that conflicts with existing schemas.
- 3. Reflective activities should lead to further iterations of activity, feedback and observation based on the reflection.** Students should be given the opportunity to close the reflection cycle by using the improved learning brought about by reflection.
- 4. Provide collaborative reflection activities focused on recent learning events.** Reflection is not only an introspective activity; the opportunity should also be given for students to discuss and reflect together.
- 5. Ask the learners to provide peer feedback or assessment.** The process of giving or receiving constructive feedback from fellow students offers significant learning benefits.

#### Educational Benefits:

The use of reflective practices leads to the following education benefits:

1. Reflection plays a critical function in learning processes and improves learning performance.
2. Reflection leads to a deeper understanding and makes the material easier to remember by integrating it into existing mental schemas in the learner's long-term memory.
3. The deeper learning and increased mental flexibility brought about by reflective practice support improved far transfer.

4. Collaborative peer reflection, in particular in a peer feedback context, improves learning motivation and learning performance.	
<b>Potential Challenges:</b>	
NA	
<b>Related Heuristics:</b>	<p>Reflective practice offers strong support in the following areas</p> <ul style="list-style-type: none"> <li>• Constructivist and Problem-based learning approaches (Heuristics: 1, 3, 4, 4.1, 6.2)</li> <li>• Intrinsic learner motivation (Heuristic 13)</li> <li>• Social and collaborative learning (Heuristic 9, 11)</li> <li>• Connectivist principles of learning networks (Heuristics 12)</li> <li>• Integrating learning into long-term memory (Heuristic 5)</li> <li>• Practice activities, explanatory feedback, scaffolding and attaining the zone of proximal development (Heuristics 7, 7.1, 8, 10).</li> </ul>

<b>ID</b>	<b>Heuristic Title:</b>		
3	Make expert and learner thinking processes explicit.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	Metacognition Higher-Order Thinking
<b>Description:</b>			
<p>Students often learn something; but, may not be clear on the rationale behind it, when to do it, how to gauge progress or whether the approach is working. The e-learning software and teachers (via the CLE) should make invisible mental processes explicit for the learner to understand and thereby implement. Likewise, learners must undertake activities to clarify and reflect on their underlying thinking and the rationale for their actions in resolving a problem.</p>			
<b>Design and Evaluation Criteria:</b>			
<p>To successfully make expert and learner thinking processes explicit, an appropriate subset of the following guidelines should be implemented in the e-learning software and CLE activities:</p> <ol style="list-style-type: none"> <li><b>1. Make solution steps and underlying thinking explicit during problem-solving.</b> During problem-solving activities, the e-learning software and teachers (via the CLE) should make the plan, implement and evaluate cycle explicit. Decisions, process steps and the underlying thinking and rationale for those decisions or steps should be made explicit via a running commentary.</li> </ol>			

2. **Focus attention on expert behaviour.** In line with kinaesthetic learning, expert behaviour should be demonstrated and the desired behaviour signposted to focus learner attention.
3. **Promote learner reflection on their own thinking processes.** Focus should be expanded beyond finding the final solution to also include opportunities for learners to comment on their progress and articulate their thinking in working on a problem. To promote further self-reflection teachers can provide feedback or students can enter into pair or group reflection in which they can discuss, justify and comment on theirs and others thinking processes.

**Implementation Tip:**

Expert thinking can be made explicit by the provision of a running commentary of the underlying thinking and rationale for decisions; this commentary can be implemented in audio, video, animation or text in the e-learning software.

The CLE can be used by the teacher to demonstrate expert behaviour and thinking. Additionally, the learners can undertake activities on the CLE to reflect on their own thinking processes.

**Educational Benefits:**

By explicitly exposing thinking processes in varying contexts the learner is able to model them, incorporate them in their own thinking and reflect on their own thinking processes. This, in turn, leads to a comparative improvement in immediate learning performance, in far transfer tests and more robust problem-solving skills.

**Potential Challenges:**

To make invisible thinking processes explicit is a challenging task that requires a high level of metacognitive skills in the teacher, or in the instructional designer designing the e-learning software. This also creates a secondary layer of metacognitive learning that may overload or distract students from the primary topic.

**Related Heuristics:**

Making expert and learner thinking processes explicit provides underlying support in the following pedagogical areas:

- Authentic learning, problem-based learning and practice activities (Heuristics 1, 4, 6, 6.1, 6.2, 7, 7.1).
- Using worked-examples and the provision of scaffolding support (Heuristics 4.1, 8).
- Engaging learners in progressively challenging learning (Heuristic 10).

	<ul style="list-style-type: none"> <li>• Fostering intrinsic motivation and intrinsic gamification elements (Heuristic 13, 15, 15.1).</li> <li>• Fostering deep learning (Heuristic 5).</li> </ul> <p>This heuristic is supported by heuristics in the areas of reflective practice, visualisation, social constructivism, collaborative learning and connectivism (Heuristics 2, 9, 11, 12, 16.1)</p> <p>However, it is important to consider that the process of making expert and learner thinking processes explicit creates a secondary layer of metacognitive learning that, if not considered with measure, may overload or distract students from the primary topic (Heuristic 18).</p>
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ID	Heuristic Title:		
4	Use problem-based learning (PBL) to facilitate learning.		
Learning Theory:	Constructivism	Pedagogical Area:	Problem-based Learning Higher-Order Thinking
Description:			
<p>Problem-based learning, in contrast to part-task instruction, focuses on the bigger picture and begins with an authentic problem or work assignment which drives the learning process in trying to solve the problem. Working on the problem takes the form of a guided discovery that integrates into the process the necessary knowledge and skills to solve the problem and arguably results in a richer more challenging learning experience.</p>			
Design and Evaluation Criteria:			
<p>To successfully apply problem-based learning requires an appropriate subset of the following guidelines be implemented in the e-learning software and collaborative learning activities:</p> <ol style="list-style-type: none"> <li><b>1. The e-learning software should include an increased focus on whole-task and guided discovery learning strategies.</b></li> <li><b>2. Select an appropriately complex and ill-structured problem.</b> To engage the learners' higher-order thinking skills, the problem used to drive learning must be suitably complex, ill-structured and preferably offer an authentic real-life scenario. However, it must also consider the intended learning outcomes, learner ability and subject knowledge in order to provide a suitable challenge without creating a cognitive overload. For further guidelines on defining an appropriately complex problem, please refer to Appendix B.3.</li> <li><b>3. Provide a suitably rich problem representation (context).</b> An essential part of PBL is a rich problem representation that not only describes the problem but also the</li> </ol>			

context in which it appears. The problem representation should be aligned with guideline-2 above and should be detailed in providing the necessary information, but without being overly prescriptive and taking away the learner's need to think.

4. **Include multiple problems / case studies to initiate the learning process and give an authentic context.** It is normal that learners may not have the mental models in place to understand the problem and to take appropriate steps towards a solution. This challenge can be reduced by providing a set of experiences (embodied in case studies) that learners can refer to. This supports learners in solving the current problem and in far transfer learning.
5. **A problem-based learning flow should be used to guide the students in the approach to tackle the problem.** Such macro-scaffolding is discussed in heuristic 8 and an example problem-based learning flow is outlined in Appendix B.2.
6. **The problem-based learning flow can be used in iterative cycles.** Depending on the size and complexity of the problem, an abridged version of the problem-based learning flow can be undertaken in cycles to identify requirements, design a solution, implement the solution, and finally test the solution.
7. **Students must be supported and educated on metacognitive processes needed in problem-based learning.** Unlike, part-task instruction, students are no longer instructed in digestible chunks of learning; they take a greater responsibility to identify what learning and what steps are necessary to solve the problem. Either teachers or the e-learning software needs to educate and support learners in the relevant metacognitive processes that enable the planning, monitoring and delivery of the problem solution.
8. **Provide a collaborative environment to support the social-interactivity inherent in problem-solving.** PBL is strongly based on social theories of learning and on the interaction of learners in negotiating a solution to the problem. This is particularly relevant for problems that are more complex. Appropriate collaborative tools should, therefore, be put in place to allow students to work together collaboratively in PBL.
9. **Provide a Problem Manipulation Environment.** The kind of mindful activity necessary in PBL requires a [problem manipulation environment](#) in which the learner is in direct contact with real or virtual objects and is encouraged to manipulate them in order to think, hypothesise and test their hypothesis.

#### Educational Benefits:

Whole-task approaches and problem-based learning provide the following educational benefits:

1. Whole-task learning either leads to comparable or improved learning performance as compared with part-task learning.
2. Whole-task learning helps students improve their higher-order thinking skills; in terms of Bloom's original taxonomy, this means a focus on application, analysis and synthesis.
3. Well-designed problem-based learning approaches prepare students to apply new skills and thinking to different problems than the ones faced in training and are superior for far-transfer learning goals.
4. Problem-based learning gives students a sense of control and challenge that can be used to increase intrinsic motivation
5. Interpersonal skills and student satisfaction are superior in learners undertaking whole-task learning.

#### Potential Challenges:

Problem-based learning is a significant shift in educational philosophy that to some extent remains out of step with current educational and assessment practices in schools, which focus on part-task teaching methods. This means that the e-learning software and the teachers intending to use the software must consider the following potential challenges.

The successful implementation of problem-based learning requires significant pedagogical and instructional design experience to provide a measure of complexity and ill structure in the problem that engages the learner's thinking processes but without causing cognitive overload. Additionally, the potential for cognitive overload should be further reduced by providing appropriate student guidance and scaffolding support on the problem itself and the surrounding process flow to solve the problem.

Similarly, the representation of the problem must be suitably rich in describing the necessary information, but not overly prescriptive; there still needs to be a curiosity for the learner to engage in trying to understand the problem and then trying to solve it.

During PBL, increased responsibility for learning is placed on the student, since the teacher's primary focus is no longer to present prescriptive knowledge, but instead to facilitate learning through problem-solving and enable just-in-time discovery of necessary knowledge. Additionally, students must become more comfortable with inductive learning in which they try different actions and reflect on the outcomes in terms of learning and problem resolution. During PBL, the guided discovery inherent in this approach, must carefully consider and balance with the structured e-learning environment (Heuristics 21, 21.1).

#### Related Heuristics:

Problem-based learning has a number of strongly related pedagogical areas such authentic learning, reflective practice, making thinking

processes explicit, kinaesthetic learning, and supporting and exemplifying PBL via computational thinking (Heuristics 1, 2, 6, 6.1, 6.2, 16.4).

An inherent part of problem-based learning is just in time learning as guided by the problem; this is strongly aligned with connectivist principles of discovering the most current and relevant learning material from the learning network (Heuristics 1.1, 12).

Building on the concept of a learning network this pedagogy aligns with problem-based learning that is collaborative in nature, therefore is supported by social and collaborative learning approaches (Heuristics 9, 10, 11).

Problem-based learning offers strong support in integrating learning into long-term memory and in increasing intrinsic motivation (Heuristics 5, 13). Additionally, it improves motivation by supporting attention, satisfaction and gamification approaches (Heuristics 14, 14.1, 14.4, 15, 15.1, 15.2), but may potentially counteract confidence building approaches (Heuristic 14.3). As advised previously, it is crucial to reduce cognitive load by offering appropriate scaffolding and support of metacognitive processes (Heuristics 3, 4.1, 7.1, 8). In particular, careful consideration must be taken to avoid cognitive overload by ensuring that the PBL directly supports intended learning outcomes and does not unduly impact the segmenting used for essential processing (Heuristics 18, 19). As mentioned previously, the guided discovery inherent in this approach must carefully consider and balance with the structured e-learning environment (Heuristics 21, 21.1).

ID	Heuristic Title:		
4.1	Use worked-examples to support problem-based learning.		
<b>Learning Theory:</b>	Constructivism Cognitive Load Theory	<b>Pedagogical Area:</b>	Problem-based Learning Higher-Order Thinking
<b>Description:</b>			
A work example is a step-by-step demonstration of how to perform a task or solve a problem and is one of the most effective methods to support learning; in particular the far transfer of			

learning and building new cognitive skills. In this context, the examples are non-trivial and involve higher order thinking to solve problems where there are potentially multiple appropriate solutions.

**Design and Evaluation Criteria:**

The successful use of worked examples in problem-solving is supported by four basic guidelines:

- 1. Gradually transition from worked examples to problems.** For best learning results present a worked example in which all the steps are worked out, then follow on examples will transition towards fewer steps being provided and more steps being done by the learner. Please refer to Figure 63.
- 2. Promote self-explanation of worked examples.** Deeper learning can be promoted by reflective practices. This can be achieved by providing reflective questions either for self-reflection or collaborative reflection in which the learners review the worked-out steps and discuss the underlying principles and rationale behind them.

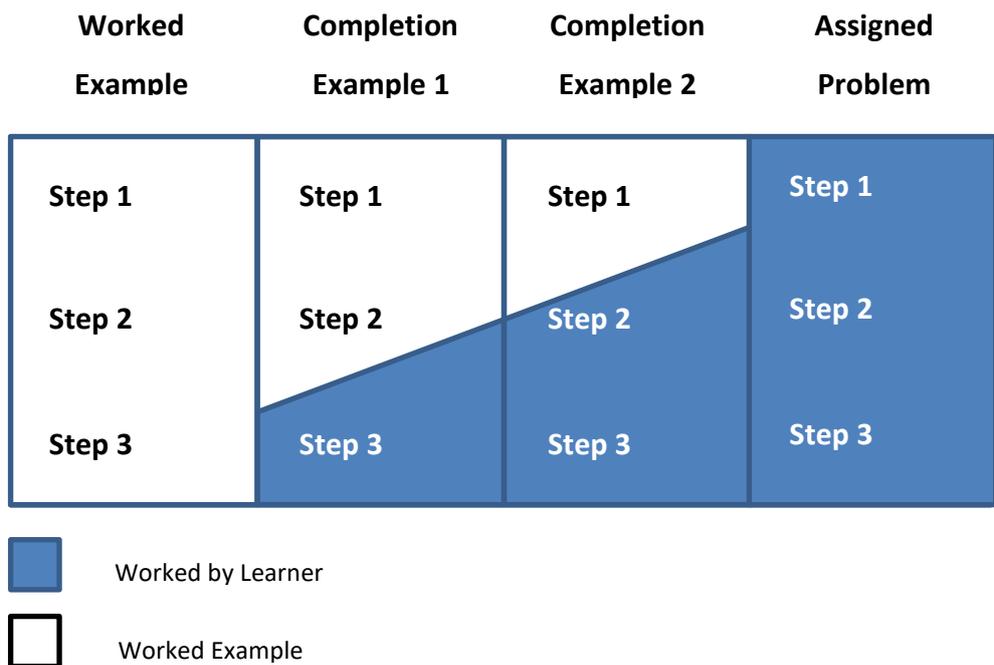


Figure 63: Gradual transition from worked examples to practice problems

(Adapted from Clark et al. 2011)

- 3. Selectively include an instructional explanation of worked-examples where appropriate.** In some circumstances, such as when conceptual understanding is the goal or where self-explanation is not used, there is a learning benefit from the inclusion of on-demand instructional explanations for worked examples.

- 4. Support far-transfer by using examples that provide the same underlying principles in different contexts.** Learning through different contexts promotes a more flexible understanding and far-transfer; it improves the learner’s ability to abstract and connect the underlying principles, which then gives them the ability to apply them in different situations.

**Educational Benefits:**

The use of worked examples provides the following educational benefits:

1. Comparing a combined lesson (worked-example followed by practice) with an all practice lesson, two findings are apparent:
  - The completion time for the combined lesson is significantly shorter than the all practice lesson.
  - The test error is significantly reduced in the combined lesson compared to the all practice lesson.
2. Comparing text-based educational material and worked-examples, learners preferred the worked examples.
3. Learning via worked-examples reduces cognitive load; whilst taking in the worked example the learner’s working memory is relatively free to borrow and reorganise new knowledge, and once this scaffolding knowledge is in place, practice helps the learner solidify the new knowledge.
4. Worked-examples enhance the development of problem schemas that in turn enable learners to recognise different types of problems that fit the problem schemas, and ultimately lead to improved far transfer.

**Potential Challenges:**

It should be noted that worked-examples are most effective during the early stages of learning a topic; for learners that are more knowledgeable, the expertise reversal effect comes into action. For novice learners the worked-examples give relief through scaffolding, but for high-knowledge learners the worked-examples at best add minimal value or at worst could conflict with the learner’s own unique approach to completing the task and hinder learning.

**Related Heuristics:**

The use of worked-examples is directly related to the social constructivist principle of scaffolding (Heuristic 8); in particular, it provides scaffolding for problem-based learning, computational thinking, practice activities and attaining the zone of proximal development (Heuristics 4, 6, 6.1, 6.2, 7, 7.1, 10)

	<p>For optimal effect, worked-examples are best used with authentic learning, reflective practices (Heuristic 1, 2) and can be used to make expert thinking processes explicit (Heuristic 3).</p> <p>Worked-examples improve motivation by supporting confidence, satisfaction and gamification (Heuristics 14, 14.3, 14.4, 15, 15.1).</p> <p>The use of worked-examples can be used to integrate learning into long-term memory (Heuristic 5) and can help in reducing cognitive load by providing scaffolding and by being combined with segmenting and pre-training strategies (Heuristic 19).</p>
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ID	Heuristic Title:		
5	Integrate learning into long-term memory by using authentic examples, and non-trivial practice and problems.		
<b>Learning Theory:</b>	Constructivism Social Constructivism	<b>Pedagogical Area:</b>	Deep Learning Far Transfer
<b>Description:</b>			
To facilitate deep learning, students must integrate new learning material into existing schemas in their long-term memory. This allows learning to move beyond memorization and fact recall and enables the more flexible application of knowledge and skills to scenarios not explicitly covered in the learning material.			
<b>Design and Evaluation Criteria:</b>			
The successful integration of learning into long-term memory requires an increased focus on whole-task instruction and in particular on implementing the following heuristics in the e-learning software and associated collaborative activities:			
<ul style="list-style-type: none"> <li>• 1: Use authentic educational material, examples and activities.</li> <li>• 2: Prompt reflective practice to support learning.</li> <li>• 3: Make expert and learner thinking processes explicit.</li> <li>• 4: Use problem-based learning (PBL) to facilitate learning.</li> <li>• 4.1: Use worked-examples to support problem-based learning.</li> <li>• 6.2: Exemplify computational thinking in problem-solving activities.</li> <li>• 9: Use social-interaction to increase learning and promote higher-order thinking.</li> <li>• 16.1: Support visual modal preference. Guideline-10, support for visualization.</li> </ul>			

**Educational Benefits:**

In creating appropriate new schemas and integrating into existing schemas the learning material becomes more deeply rooted in the learner, this enables them to recall the knowledge and skills longer into the future and also allows them to apply this knowledge in different contexts. In short, the learner becomes a more flexible problem solver.

Furthermore, the majority of the approaches used in this heuristic positively influence intrinsic motivation and satisfaction, it, therefore, follows that this heuristic positively influences intrinsic motivation.

**Potential Challenges:**

Please refer to the Potential Challenges section in the heuristics listed in the Design and Evaluation Criteria section above.

**Related Heuristics:**

As outlined in the Design and Evaluation Criteria section, this heuristic is implemented via the following heuristics:

- 1: Use authentic educational material, examples and activities.
- 2: Prompt reflective practice to support learning.
- 3: Make expert and learner thinking processes explicit.
- 4: Use problem-based learning (PBL) to facilitate learning.
- 4.1: Use worked-examples to support problem-based learning.
- 6.2: Exemplify computational thinking in problem-solving activities.
- 9: Use social-interaction to increase learning and promote higher-order thinking.
- 16.1: Support visual modal preference. Guideline-10, support for visualization.

In addition, this heuristic improves intrinsic motivation, supports learner satisfaction and supports intrinsic gamification elements (Heuristics 13, 14, 14.4, 15, 15.1). However, the focus on authentic learning and problem-based learning must be considered in relation to their impact on cognitive load (Heuristics 18, 19).

<b>ID</b>	<b>Heuristic Title:</b>		
6	Support problem-solving through computational thinking.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	Computational Thinking
<b>Description:</b>			
<p>Computational thinking is a way of thinking based on computer science concepts in order to reformulate and solve problems. There currently is no authoritative definition of what these computer science thought processes are, but one stable definition involves six concepts: a thought process, abstraction, decomposition, algorithmic design, evaluation, and generalisation. computational thinking is both an important computer science topic that arguably deserves its own pedagogical heuristics, but also a way of thinking that influences the heuristics for problem-solving.</p>			
<b>Design and Evaluation Criteria:</b>			
<p>To successfully implement this heuristic the instructional design and implementation of the e-learning software and CLE activities should consider the following sub-heuristics:</p> <ul style="list-style-type: none"> <li>• 6.1: Build a foundation for computational thinking.</li> <li>• 6.2: Exemplify computational thinking in problem-solving activities.</li> </ul>			
<b>Educational Benefits:</b>			
<p>It is theorised that an understanding of computational thinking provides a set of mental tools that can be used in higher-order thinking and problem-solving that extends beyond the computer science domain.</p>			
<b>Potential Challenges:</b>			
<p>There remains a variety of academic and pedagogic interpretations of what computational thinking is, what differentiates it from other thinking skills, how best to teach it, and what can realistically be expected from children. This lack of clarity causes challenges in ensuring consistent curriculum design, appropriate assessment and in designing pedagogical strategies to teach computational thinking.</p> <p>It is intuitively understood by computer scientists, supported by government initiatives, and theorised by academics that an understanding of computational thinking leads to improved problem-solving. However, the empirical evidence to link computational thinking to improved problem-solving or far transfer to other problem domains is not conclusive.</p>			
<b>Related Heuristics:</b>	<p>Support for computational thinking is implemented through the following heuristics:</p> <ul style="list-style-type: none"> <li>• 6.1: Build a foundation for computational thinking.</li> </ul>		

	<ul style="list-style-type: none"> <li>6.2: Exemplify computational thinking in problem-solving activities.</li> </ul> <p>The teaching of computational thinking offers direct support for problem-based learning (Heuristics 4, 6) and is aligned with authentic learning (Heuristic 1). These direct links to problem-based learning and authenticity also positively influence intrinsic motivation (Heuristic 13). Computational thinking is also effective in supporting practice activities, scaffolding, feedback, making thinking processes explicit and helping learners reach their ZPD (Heuristics 3, 4.1, 7, 7.1, 8, 10).</p> <p>It is also important to note that underlying computational thinking is an ethos of teamwork and social interaction; hence, there is a direct link to both social and collaborative learning (Heuristics 9, 11).</p> <p>The guided discovery inherent in PBL based approaches must carefully consider and balance with the structured e-learning environment (Heuristics 21, 21.1).</p>
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ID	Heuristic Title:		
6.1	Build a foundation for computational thinking.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	Computational Thinking
Description:			
<p>Before students can employ computational thinking, they must first have a clear foundation on what are the elements of computational thinking, be presented with real-world examples to broaden their knowledge base, and become comfortable with the use of computational vocabulary to describe problems and solutions. This acts as scaffolding or pre-training before students start using computational thinking techniques.</p>			
Design and Evaluation Criteria:			
<p>To successfully build a foundation for computational thinking, the e-learning software or teacher-led instruction should implement scaffolding / pre-training in line with the following guidelines:</p> <ol style="list-style-type: none"> <li><b>1. Emphasise to students that the focus is not on creating tangible artefacts but about fostering specific thought processes.</b></li> <li><b>2. Provide to students a clear definition of the following computational thinking concepts: abstraction, decomposition, algorithmic design, evaluation, and generalisation.</b></li> </ol>			

<ol style="list-style-type: none"> <li>3. <b>Make use of computational vocabulary to describe problems and solutions to increase the students' comfort with concepts and terminology.</b></li> <li>4. <b>Bring computational thinking concepts to life with the use of real-world examples.</b></li> <li>5. <b>Make computational thinking more tangible to students by exemplifying it using algorithms either represented as flowcharts or pseudocode.</b></li> </ol>	
<b>Educational Benefits:</b>	
Please refer to Educational Benefits listed in heuristic 6.	
<b>Potential Challenges:</b>	
Please refer to Potential Challenges listed in heuristic 6.	
<b>Related Heuristics:</b>	The foundation to computational thinking provided in this heuristics acts as scaffolding or pre-training (Heuristics 8, 19) before learners use computational thinking approaches (Heuristics 6, 6.2). It is used in combination with authentic learning and making thinking processes explicit (Heuristics 1, 3) to support worked-examples, scaffolding and feedback on practice activities (Heuristics 4.1, 7, 7.1, 8). Ultimately, the objective of this heuristic and computational thinking, in general, is to support problem-based learning (Heuristic 4).

<b>ID</b>	<b>Heuristic Title:</b>		
6.2	Exemplify computational thinking in problem-solving activities.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	Computational Thinking
<b>Description:</b>			
Once a stable foundation of computational thinking concepts and terminology is established, we must exemplify the ethos, approaches and concepts used in computational thinking through worked examples and problem-solving activities that learners can actively engage in.			
<b>Design and Evaluation Criteria:</b>			
To successfully exemplify computational thinking the instructional design and implementation of the e-learning software and CLE activities should consider the following guidelines:			
<ol style="list-style-type: none"> <li>1. <b>Use problem-solving activities and worked examples as a vehicle to use and exemplify computational thinking practice.</b> (Heuristics 4, 4.1)</li> <li>2. <b>Make computational thinking processes explicit to learners whilst walking through worked examples and problem-solving activities.</b> (Heuristic 3)</li> <li>3. <b>Use a three-stage progression model: Use-Modify-Create.</b> Use-Modify-Create is a pattern of engagement that initially scaffolds the learning process and then</li> </ol>			

progressively removes that scaffolding (Similar to heuristic 4.1). Initially, students are consumers of someone else's creation, then they modify the model, game or program etc. with increasing sophistication until eventually they have learnt the skills to create entirely new models, games or programs.

- 4. Use a Problem Manipulation Environment for students to engage in computational thinking.** A fundamental prerequisite for guideline-3 is the provision of a rich problem manipulation environment in which the learner can be immersed in the Use-Modify-Create approach; the key consideration is to provide learners with a number of mindful activities in which they can engage in. A number of such activities are outlined in Appendix E.
- 5. Instil in learners the ethos behind computational thinking.** As well as a set of concepts that guide thinking processes, computational thinking also has an underlying ethos that guides how to approach the problem. The computational thinking ethos is discussed further in Appendix B.4.

#### Educational Benefits:

Please refer to Educational Benefits listed in heuristic 6. In addition, the focus of this heuristic on authentic learning, activities and problem-solving means it offers a positive influence on intrinsic motivation (Heuristic 13).

#### Potential Challenges:

Please refer to Potential Challenges listed in heuristic 6.

#### Related Heuristics:

Exemplifying computational thinking in problem-solving activities builds upon heuristic 6.1 to implement heuristic 6. It is used in combination with authentic learning, reflective practice and making thinking processes explicit (Heuristics 1, 2, 3) to support worked-examples, scaffolding and feedback on practice activities, and kinaesthetic learning (Heuristics 4.1, 7, 7.1, 8, 16.4). Additionally, since the ethos behind computational thinking is team-based, it integrates with social, collaborative and connectivist learning (Heuristics 9, 10, 11, 12). The approaches used in exemplifying computational thinking help to improve intrinsic motivation and integrate learning into long-term memory (Heuristic 5, 13) with the ultimate objective of supporting problem-based learning (Heuristic 4). Additionally, it influences learner motivation by supporting attention, satisfaction and gamification approaches (Heuristics 14, 14.1, 14.4, 15.1). The focus of this heuristic on authentic learning, activities and problem-solving means that careful

	<p>consideration should also be given to managing cognitive load (Heuristics 18, 19).</p> <p>In addition, the guided discovery inherent in PBL based approaches must carefully consider and balance with the structured e-learning environment (Heuristics 21, 21.1).</p>
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ID	Heuristic Title:		
7	Distribute well-designed practice activities across the lesson to support learning.		
Learning Theory:	Constructivism	Pedagogical Area:	Active Learning Practice and Feedback
Description:			
<p>Practice activities should be distributed throughout the e-learning software to support and solidify learning, rather than as an assessment of learning. The design of these activities should be for the student to apply their learning and promote further thinking, instead of shallow activities such as recognising or reiterating facts.</p>			
Design and Evaluation Criteria:			
<p>High performers devote more time towards practice; however, this is not sufficient, the following additional guidelines must be considered in the instructional design and implementation of the e-learning software and CLE activities:</p> <ol style="list-style-type: none"> <li>1. <b>Practice activities should be integrated into the learning experience to support and solidify learning, instead of focusing them as an assessment.</b> Practice activities should be integrated within learning material and therefore should be guided by the same heuristics intended for learning content.</li> <li>2. <b>The number and distribution of practice activities need to be carefully considered in relation to intended learning outcomes.</b> <ol style="list-style-type: none"> <li>a) Where automaticity is required, assign a large number of practical activities.</li> <li>b) For short-term retention (exam revision), practice activities should be massed.</li> <li>c) For long-term retention, distribute practice among lessons in the course, within a given lesson and among learning events.</li> <li>d) To extend learning, use asynchronous practice activities between sessions.</li> </ol> </li> <li>3. <b>Practice activities should be designed for the student to apply their learning and promote further thinking,</b> minimising <b>shallow</b> activities such as recognising or reiterating facts.</li> </ol>			

**4. Practice activities should provide variety and intrinsic motivation.** Design practice activities to be intrinsically motivational (Heuristics 13, 14) and provide a variety of practice activity types to maintain optimum engagement; for instance, a variety of simulation activities, problem-solving, short answer, multiple choice (that are not focused on memory retention) and collaborative work.

**Implementation Tip:** The multimedia and multi-modal (Heuristic 16) capabilities of the e-learning software can be used to represent engaging practice activities. Collaborative activities and self-reflection activities can be supported by the CLE and other VOIP<sup>5</sup> based communication software (e.g. SKYPE, Viber, and FaceTime).

#### Educational Benefits:

Well-designed practice activities can improve student performance almost indefinitely to elite status.

- In early sessions, it leads to improved performance as the learner improves their approach to completing the task.
- In later practice sessions, automaticity increases the learner's efficiency and speed in implementing their approach.

As discussed in the heuristics on motivation, practice activities can also be used to positively influence learners' intrinsic motivation.

#### Potential Challenges:

The addition of interactive practice activities promotes learning, but some balance is necessary not to overload the learner. For example, if a learner is asked to select a correct answer, it is appropriate to follow this with a reflective question to ask why they believe it is correct. Whereas if a learner is given an activity that is cognitively more involving, working through to a correct answer, then it would likely be redundant and overload the learner to then ask an associated explanation question.

Furthermore, it is essential to understand that practice can improve student performance almost indefinitely to elite status, but with diminishing returns that must be considered.

**Related Heuristics:** The provision of well-designed practice activities requires consideration of almost all heuristics defined in this pedagogy. In particular, they are closely related to constructivist approaches such as authenticity, reflective practice, active learning and mindful activity (Heuristics 1, 2,

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<sup>5</sup> Voice Over Internet Protocol (VOIP) is technology to allow phone services over the Internet.

4). Additionally, practice activities support the instruction of computational thinking (Heuristics 6, 6.1, 6.2). They are closely aligned with the provision of worked-examples, making thinking processes explicit, providing explanatory feedback and the provision of scaffolding (Heuristic 3, 4.1, 7.1, 8). Practice activities should also support multi-modal learning and visualisation (Heuristics 16, 16.1, 16.2, 16.3, 16.4) and a subset of practice activities should also build upon social and collaborative learning and learning networks (Heuristics 9, 10, 11, 12). One of the most important areas of positive influence of practice activities is in motivation. Specifically intrinsic motivation, gamification, gaining learner attention, and building learner confidence and satisfaction (Heuristics 13, 14, 14.1, 14.3, 14.4, 15, 15.1, 15.2). However, as with all learning material, practice activities must consider cognitive load and in particular, must focus on direct support of instructional goals (Heuristic 18).

ID	Heuristic Title:		
7.1	Provide explanatory feedback to practice activities to promote learning.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	Active Learning Formative Assessment
<b>Description:</b>			
Explanatory feedback on practice activities is a further opportunity to promote learning, instead of focusing solely on assessment. In comparison to other factors influencing learning, integrating explanatory feedback into the learning process is one of the most effective.			
<b>Design and Evaluation Criteria:</b>			
To increase the effectiveness of explanatory feedback, the following guidelines must be considered in the instructional design and implementation of the e-learning software and CLE activities:			
<ol style="list-style-type: none"> <li>1. <b>Provide feedback that tells the learner whether the answer is correct or incorrect accompanied by a succinct explanation.</b></li> <li>2. <b>The explanation should provide cues, reinforcement or information on how to successfully complete a task or achieve learning goals.</b></li> <li>3. <b>Feedback should be provided at, or just above, the level where the student is learning.</b></li> </ol>			

4. **Position the feedback in close proximity to both the question and answer, so the learner can see all together.**
5. **Feedback should focus on the task or task process and not on the learner.** Praise or criticism tends to focus on the individual, impacts the ego, and does very little to improve learning.
6. **Emphasise progress feedback that shows improvement over time.**
7. **Feedback should be used to complete the feedback loop.** Students should be given the opportunity to produce improved work in consideration of the feedback.
8. **In more complex problem-solving activities, that include multiple steps, it is essential to provide step-wise feedback.** This avoids the situation where an early misstep derails the whole problem-solving process.

#### Educational Benefits:

- A synthesis of over 800 meta-analyses relating to learning achievement identified 138 influencing factors, of which the integration of constructive explanatory feedback into the learning process is ranked highly in 10<sup>th</sup> place.
- Furthermore, improved learning performance is achieved from explanatory feedback as compared to corrective feedback.
- Additionally, students report that they find explanatory feedback more helpful.

#### Potential Challenges:

The increased instructional efforts in providing explanatory feedback are significant and should not be underestimated; however, in e-learning software, these additional efforts are largely mitigated due to economies of scale.

#### Related Heuristics:

Explanatory feedback is a strategy that underpins a number of other pedagogical areas, such as reflective practice, making expert thinking explicit, supporting practice activities, problem-based learning, worked examples, social learning, scaffolding, building learner confidence and satisfaction, gamification and supporting the zone of proximal development (Heuristics 2, 3, 4, 4.1, 6, 6.1, 6.2, 7, 8, 9, 10, 11, 12, 13, 14, 14.3, 14.4, 15, 15.1).

ID	Heuristic Title:		
8	Provide scaffolding to advance learning progress.		
Learning Theory:	Social Constructivism	Pedagogical Area:	Active Learning Learning Support
<b>Description:</b>			
Scaffolding is the process by which a teacher or other guiding figure (including the e-learning software and even more knowledgeable students) provide additional instructional assistance, guidance, or prompting that supports a student's learning process so they can accomplish an activity that is usually out of their reach.			
<b>Design and Evaluation Criteria:</b>			
To effectively support scaffolding approaches the following guidelines must be considered in the instructional design and implementation of the e-learning software and CLE activities:			
<ol style="list-style-type: none"> <li>1. <b>Choose appropriate scaffolding or combination of scaffolding approaches for the situation:</b> <ol style="list-style-type: none"> <li>a. <b>Macro-scaffolding</b> – Provides high-level guidance on how to approach a learning task or problem activity. It can give a general workflow to be followed in order to accomplish the desired learning outcomes</li> <li>b. <b>Micro-scaffolding</b> - Provide scaffolds for solving detailed actions that focus on specific learning activities.</li> <li>c. <b>Automated Scaffolding</b> – Automated scaffolding is Macro or Micro-scaffolding that is incorporated in the instructional design and is delivered by the e-learning software.</li> <li>d. <b>Social-Scaffolding</b> – Macro or Micro-scaffolding provided by some form of social interaction with a teacher or other guiding figure.</li> </ol> </li> <li>2. <b>Choose a variety of scaffolding techniques to include, such as:</b> <ol style="list-style-type: none"> <li>a. Use explanatory feedback to support student learning (Heuristic 7.1).</li> <li>b. Use screencasts that focus on detailed actions on specific learning activities.</li> <li>c. Use simulations, animations and other visualization tools to help learners construct their mental images and visualize activities (Heuristic 16.1 guideline-10).</li> <li>d. Pre-plan for students to request scaffolding on some low-level tasks, by including a "<i>Hint</i>" button that can be used when needed.</li> <li>e. Provide worked-examples that gradually transition to full problems (Heuristic 4.1).</li> </ol> </li> </ol>			

- f. Present related cases studies - Providing case studies with different contexts but the same underlying principles supplies the learner with a rich set of experiences to guide them in resolving the current problem.
- g. Articulate Reasoning – An expert model’s problem-solving or other skills, and articulates the implicit reasoning and decision making involved in each step of the process (Heuristic 3).
- h. Behavioural Modelling – Expert behaviour is modelled by demonstrating how to perform certain activities and signalling important steps (Heuristic 3).

**3. Gradually remove scaffolding support as learners advance and develop their own learning strategies.**

**Educational Benefits:**

The use of scaffolding provides the following educational benefits:

1. It supports learners in trying to reach their full potential and the expected learning outcomes.
2. It reduces cognitive load during constructivist and whole-part instruction, thereby mitigating the potential for cognitive overload in using constructivist or whole-part instructional approaches.
3. Students report that they prefer scaffolded learning approached.

**Potential Challenges:**

Scaffolding support should be gradually removed as learners advance and develop their own learning strategies; otherwise, it may frustrate advanced learners or impede the progress of learners to more advanced levels.

**Related Heuristics:**

This heuristic closely supports reflective practice, practice activities, problem-based learning and the zone of proximal development (Heuristic 2, 4, 6, 6.2, 7, 10) and is related to reducing cognitive load (Heuristics 18, 19). It is implemented by making thinking processes explicit, using worked-examples, defining computational thinking concepts, providing explanatory feedback, social and collaborative learning, and learning networks (Heuristics 3, 4.1, 6.1, 7.1, 9, 11, 11.1, 12). The level of scaffolding also influences gamification and the activities proposed within confidence and satisfaction approaches (Heuristics 14, 14.3, 14.4, 15, 15.1).

<b>ID</b>	<b>Heuristic Title:</b>		
9	Use social-interaction to increase learning and promote higher-order thinking.		
<b>Learning Theory:</b>	Social Constructivism	<b>Pedagogical Area:</b>	Social Learning
<b>Description:</b>			
<p>Social constructivism builds upon cooperative and collaborative learning, and reflective learning practices to emphasise the importance of social interactions in shaping the learner’s knowledge construction. It supports learners in reaching a higher level of learning than what can be achieved individually. In addition, the social interaction of individuals can often lead to learning that is greater than the sum of the individuals, and can ultimately result in a shared understanding inherently derived from the learning community.</p>			
<b>Design and Evaluation Criteria:</b>			
<p>To successfully implement social learning the instructional design of the e-learning software and CLE activities should consider an appropriate subset of the following:</p> <ol style="list-style-type: none"> <li><b>1. Use social-interaction to foster the learner’s ability to develop and evaluate their opinion in relation to other people’s opinions.</b> The e-learning software and collaborative learning activities (supported by teachers) should give an increased focus on social (collaborative) activities that foster students’ ability to develop an opinion, evaluate their own and other people’s opinions, justify their thinking and openly discuss their interpretation.</li> <li><b>2. Provide a suitable learning environment and context for social-interaction.</b> The activities in guideline-1 always involve an open dialogue typically within a community of learners. The instructional design of the e-learning software and collaborative activities should provide an authentic context typically within a problem-based learning (PBL) approach, in which learners cooperate and learn together to solve a non-trivial authentic problem.</li> <li><b>3. Provide expert knowledge, behaviour and guidance.</b> Social-interaction is not restricted to only other learners; it is also facilitated by a more knowledgeable other. This can often take the form of a cognitive apprenticeship where teachers (the experts) work alongside students (the apprentices) within a situated context. The e-learning software and/or the teacher (via the CLE) act as the expert to demonstrate appropriate behaviour and offers scaffolding to support the apprentices in working on a problem or activity.</li> </ol>			
<b>Educational Benefits:</b>			
Social constructivist learning interactions offer the following educational benefits:			

1. The primary benefit is to promote higher-order thinking by encouraging learners to develop, evaluate, and appreciate multiple perspectives on an issue; this can ultimately lead to a shared consensual meaning, or if not, at least individual learning that is informed by other perspectives.
2. The underlying principles and collaborative nature of social constructivism also lead to greater student engagement and learning that is more meaningful.
3. Although not explicit instructional objectives, social constructivism also allows the sharing of learner workload through cooperative learning and the building of consensus through collaboration.
4. Social scaffolding approaches can help reduce cognitive load, thereby mitigating the potential for cognitive overload.

#### Potential Challenges:

It is important to note that there remains a significant need for individual learning, not all learning should be made social and not all learning material is suitable for social learning. Additionally, some learners, such as those with a dominant read-write modal preference (Heuristic 16.3), are typically less responsive to social learning as others.

It should also be noted that to some extent social learning remains out of step with current educational and assessment practices in schools.

Although social scaffolding approaches can help reduce cognitive load, in general, the overhead associated with social and collaborative learning can also increase student cognitive load.

#### Related Heuristics:

Social learning builds upon constructivist values (Heuristics 1, 1.1, 2, 4, 5, 6, 6.2) to add a social and collaborative dimension (Heuristics 8, 10, 11, 11.1). Social learning integrates well with pedagogical approaches that focus on making expert thinking explicit, practice activities and explanatory feedback (Heuristics 3, 7, 7.1). It aligns well with connectivist principles, in particular, the use of learning communities (Heuristic 12). It improves motivation by gaining learner attention, reinforcing relevance and satisfaction (Heuristic 14, 14.1, 14.2, 14.4), and gives underlying support to gamification principles (15, 15.1, 15.2). As a basis for social dialogue, it is reinforced by approaches that emphasise a conversational style in screen text and audio narration (Heuristic 20) within the e-learning software. However, it is important to note that not all learning is appropriate for social learning and in particular, not all learners favour social learning (Heuristic 16.3). The

	social scaffolding in guideline-3 helps reduce cognitive load (Heuristics 18, 19) and also influences gamification and the activities proposed within ARCS confidence and satisfaction approaches (Heuristics 14, 14.3, 14.4, 15, 15.1). However, in general, the overhead associated with social and collaborative learning can increase cognitive load (Heuristics 18, 19).
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ID	Heuristic Title:		
10	Engage learners in a challenge; target learning towards the zone of proximal development (ZPD).		
Learning Theory:	Social Constructivism	Pedagogical Area:	Active Learning Setting Challenge
Description:			
<p>The zone of proximal development (ZPD) is a theoretical space of understanding which is just above the level of understanding of a given individual and which can only be reached with support. It is the necessity of support by others that explains the importance of social interaction for learning development. It should be noted that the role of the more knowledgeable other is not a role reserved only for the teacher; it is often taken by a more capable peer.</p>			
Design and Evaluation Criteria:			
<p>The zone of proximal development can be supported in the e-learning software and CLE through the implementation of a subset of the following guidelines:</p> <ol style="list-style-type: none"> <li><b>1. Educational material should progressively increase in challenge and maintain the learner at the upper limits of their current learning capacity.</b> The difficulty level of educational material and activities should progressively increase as the learner progresses, thus encouraging the students to work at the upper limits of their current learning capacity.</li> <li><b>2. Teachers should be able to easily update text and visual learning material to be more challenging.</b> The e-learning software should provide the technical affordance for teachers and instructional designers to easily update text and visual learning material to be more challenging to their student audience.</li> <li><b>3. Learners should be supported with scaffolding and access to more knowledgeable others.</b> In order to avoid feelings of disappointment, learners must have comprehensive scaffolding support (Heuristic 8) and access to more knowledgeable</li> </ol>			

others who can give assistance in reaching the next learning level, or when the learning process is blocked.

4. **Learners should have access to a learning community.** A collaborative learning environment (CLE) should be provided to support the community of learning and facilitate social interactions between learners and more knowledgeable others. Within the community of learning, there will be multiple overlapping ZPDs, and the social interaction between students of different ZPD levels will drive an overall improvement in levels of understanding.
5. **Provide learning content and activities that adapt to the learner's current abilities and progress.** Adaptive e-learning software can automatically adjust to each learner's current knowledge and skill level and progress to material, activities and questions that are more challenging, or alternatively, revisit previous material if the learner has not adequately mastered it.

#### Educational Benefits:

The educational benefit of ZPD is that it motivates learning that stretches the learner's existing capabilities and encourages them to the next higher level of learning.

#### Potential Challenges:

In an idealised situation, the teacher or more knowledgeable other must recognise the individual learner's current state of understanding and plan accordingly to stimulate and support learning at the next higher level. This is a very difficult task for teachers and instructional designers to achieve with a class of students. This poses a risk when setting progressively challenging learning material that some learners may be left behind or become disappointed. This should be mitigated by the use of scaffolding and individualised support via the collaborative learning environment.

Another approach is to implement adaptive learning into the e-learning software; however, this too must be considered in relation to the significant additional effort in creating supplementary educational content, multiple adaptive learning pathways and the complexities and additional development of the software.

#### Related Heuristics:

This heuristic provides an underlying strategy that fundamentally affects the implementation of other heuristics since it recommends that learning material and practice activities should be set at a level that progressively challenges the learner's current capability (Heuristics 4, 6, 6.2, 7).

In order to support the increased learning challenge an increased focus should be made in making thinking processes explicit, reflective

	<p>practice, explanatory feedback, worked-examples and scaffolding (Heuristics 2, 3, 4.1, 7.1, 8). Furthermore, in order to support the zone of proximal development an increased focus on social and collaborative learning, and learning communities is necessary (Heuristics 9, 11, 12).</p> <p>The increased learning challenge also has a direct impact on building confidence and satisfaction in learners and in gamification approaches (Heuristics 14, 14.3, 14.4, 15, 15.1, 15.2).</p> <p>It is particularly important that to offset the increased learning challenge attention must be given to implementing heuristics that reduce cognitive load (Heuristics 17, 17.1, 17.2, 18, 19) and providing a structured e-learning environment (Heuristics 20, 21,21.1).</p>
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ID	Heuristic Title:		
11	Use collaborative learning activities.		
Learning Theory:	Collaborative Learning	Pedagogical Area:	Social Learning
Description:			
<p>The integration and construction of knowledge into mental models (schemas in long-term memory) happens on an individual level; however, it is evident that other people affect the learning process and that arguably learning most naturally occurs, not in isolation, but when students work together. Collaborative learning capitalizes on other people’s knowledge, skills and resources; allowing learners to monitor each other’s work, share information, summarise points, verify and test their knowledge, and debate their opinions.</p>			
Design and Evaluation Criteria:			
<p>In order to maximise the benefits of collaborative learning, the instructional design of the e-learning software and collaborative activities should incorporate a subset of the following guidelines:</p> <ol style="list-style-type: none"> <li><b>1. Ensure social interdependence of the group.</b> In collaborative learning, incentives (feedback and/or grading) should be based on a synthesis of individual and group outcomes, aligned to ensure that each team member participates and supports the learning of the rest of the team.</li> <li><b>2. Design the collaborative activity based on intended learning outcomes.</b> The desired outcome of the collaboration must be considered from the outset and the activity designed accordingly. The outcome of collaborative learning typically falls into two</li> </ol>			

main areas: either improved individual learning, or an increase in the quality of the project deliverable(s). However, since individual achievement does not necessarily correlate with group achievement or the quality of group deliverables, it is critical to decide from the outset what the expected outcome from the collaboration is.

**3. Design the collaborative activity to ensure the quality of the collaborative dialogue.**

The design of collaborative activities must ensure substantive contributions by all team members. Poor instructional design can lead learners to shallow or non-participation in collaborative activities. Avoid difficult activities that have incentives that encourage one or two individuals to take on most of the work, or activities that are too easy, unstructured or not designed to promote discussion or true collaboration.

**4. Provide structure and support for collaborative activities**

- a. Clearly communicate objectives and deliverables for the collaborative activity.
- b. Provide relevant instructions, guidance, problem description and context information for the collaboration; at least enough information to start further enquiry.
- c. Consider assigning roles to the group members to provide structure to the process (e.g. solution creator, reviewer, moderator etc.). The roles can then be switched to ensure equal coverage.
- d. If necessary, teachers may need to intercede and act as a facilitator for the collaboration.

**5. Consider team size and composition.** Team composition should either be heterogeneous teams consisting of high and low prior knowledge learners, or homogeneous teams consisting of high prior knowledge learners. Avoid homogeneous teams consisting of low prior knowledge learners.

- a. If individual learning is the outcome goal, then consider pair work.
- b. If creative problem-solving is the outcome goal, then consider a larger group of three to five team members.

**6. Prepare students for collaborative activities.** Ensure the team have sufficient social skills to manage conflict and that interactions are directed towards rational debate. This can be accomplished by pre-training or by setting appropriate guidelines.

Although slightly dated and not explicitly focused on technology-enhanced collaborative learning, an excellent primer for teachers regarding collaborative learning is: *Circles of learning. Cooperation in the Classroom* (Johnson et al. 1984).

#### **Collaborative Technologies:**

In order to support collaborative and social-learning, the e-learning software should be supplemented by a collaborative learning environment (CLE). Students using the e-learning software should also be registered on the CLE, and the e-learning software will then direct learners to the CLE to undertake collaborative activities. The CLE should implement a number of the following collaborative technologies:

<b>Blog and Micro-blogs</b>	<b>Voice Over Internet Protocol (VOIP)</b>	<b>Discussion (Message) Boards</b>
<b>Breakout Rooms</b>	<b>E-Mail</b>	<b>Social Networks</b>
<b>Text Chats</b>	<b>Online Conferencing</b>	<b>Wikis</b>
<b>e-portfolios</b>	<b>Cloud Office Applications</b>	

For more information and examples of these collaborative technologies, please refer to Appendix B.5.

#### **Educational Benefits:**

The benefits of collaborative learning include:

1. Under certain conditions, collaboration can substantially improve student achievement.
2. It can improve long-term retention and support higher-order thinking, metacognition and problem-solving by encouraging learners to develop, evaluate, and appreciate multiple perspectives on an issue.
3. It can lead to greater student engagement and learning that is more meaningful.
4. It allows the sharing of learner workload through cooperative learning and building consensus through collaboration.

#### **Potential Challenges:**

As outlined in heuristic 9, there remains a significant need for individual learning; not all learning should be made collaborative and not all learning material is suitable for collaborative learning. Additionally, some learners, such as those with a dominant read-write modal preference (Heuristic 16.3), are not as responsive to collaborative learning as others.

An important factor is that technology-enhanced collaborative learning offers limited value in a classroom context in which students can much more naturally collaborate in person.

It should also be noted that to some extent collaborative learning remains out of step with current educational and assessment practices in schools.

As discussed in heuristic 9, collaborative learning can be used as a social scaffold, therefore helping to reduce cognitive load; however, in general, the overhead associated with social and collaborative learning can increase student cognitive load.

**Related Heuristics:**

Collaborative learning integrates well with constructivist values (Heuristics 1, 1.1, 2, 4, 6, 6.2, 13) and offers direct support for social learning (Heuristics 8, 9, 10, 11, 11.1). Collaborative learning integrates well with pedagogical approaches that focus on making expert thinking explicit, practice activities and explanatory feedback (Heuristics 3, 7, 7.1). It aligns well with connectivist principles, in particular, the use of learning communities (Heuristics 12), it improves motivation by helping to gain attention, establish relevancy and reinforce learner satisfaction (Heuristic 14, 14.1, 14.2, 14.4) and gives underlying support to gamification principles (15, 15.1, 15.2). However, it is important to note that not all learning is appropriate for collaborative learning and in particular, not all learners favour collaborative learning (Heuristic 16.3).

As discussed in heuristic 9, collaborative learning used for scaffolding purposes helps reduce cognitive load (Heuristics 18, 19), but in general, the overhead associated with social and collaborative learning can increase cognitive load (Heuristics 18, 19).

ID	Heuristic Title:		
11.1	Support collaborative and situated learning via mobile devices.		
Learning Theory:	Collaborative Learning	Pedagogical Area:	Mobile Learning
Description:			
Arguably, we are currently living through a paradigm shift from education in formal settings, towards education that extends beyond the classroom to become more situated, personal, collaborative and informal. This paradigm shift is supported by the explosion of mobile devices, their significantly enhanced capabilities, pervasive wireless networks and cloud computing that enable communication, collaboration and sharing of information resources almost anywhere.			
Design and Evaluation Criteria:			
To support mobile learning (m-learning), the following guidelines should be considered:			

- 1. The instructional design of the e-learning software and collaborative learning activities should support asynchronous usage (self-directed learning).**
- 2. The implementation of the e-learning software should be developed considering technologies that are commonly accessible on mobile devices** (e.g. Web browsers and HTML5, etc.)
- 3. The instructional design and implementation of the e-learning software should support “responsive design”** enabling intrinsic support for the form factor and characteristics of mobile devices.
- 4. The instructional design and implementation of the e-learning software should be enhanced to take advantage of learning opportunities only available on mobile devices** (i.e. location awareness, device to device communication, gyroscopic control, etc.).

#### **Educational Benefits:**

There are three main benefits of supporting mobile devices for e-learning:

1. Today’s mobile devices are ubiquitous; enhancing the e-learning software for use with mobile devices immediately increases the access points available for the software.
2. By design, mobile devices excel at multimedia presentation, communication and collaboration.
3. Learning can happen anywhere; the inherent mobility of mobile devices means student learning is no longer confined to the classroom, it can happen almost anywhere either formally or in an informal context.

#### **Potential Challenges:**

Although, there is a general increase in the size of mobile phones and a trend towards larger size phablets; there remains a concern that the relatively small form factor of mobile devices may pose some restrictions on the educational content and inhibit true active engagement, thereby increasing the risk that m-learning may lead to more passive information consumption.

As noted in the parent heuristic, an important factor is that technology-enhanced collaborative learning offers limited value in a classroom context in which students can much more naturally collaborate in person.

It should also be noted that to some extent m-learning is out of step with current educational and classroom practices in high-schools and as such may not be an immediate priority to be supported by e-learning software.

<b>Related Heuristics:</b>	<p>Mobile devices are collaborative by nature; hence this heuristic relates to many of the heuristics outlined by its parent (Heuristic 11). As a mobile device it can offer greater support for situated learning and hence the authenticity and currency of learning (Heuristics 1, 1.1), but may offer comparatively weaker support for active and activity based learning approaches (Heuristics 2, 3, 4, 4.1, 5, 6, 6.2, 7, 7.1, 10). It aligns well with social learning and connectivist principles, in particular, the use of learning communities (Heuristics 8, 9, 12), it improves motivation by reinforcing learner satisfaction (Heuristic 14, 14.4) and gives underlying support to gamification principles (15, 15.1, 15.2). The multimedia, multi-modal, and portable capabilities of mobile devices offer stronger support for aspects of multi-modal learning (Heuristic 16, 16.1, 16.2, 16.3, 16.4). However, as previously noted, not all learning is appropriate for collaborative learning and in particular, not all learners favour collaborative learning (Heuristic 16.3). The technical affordances of mobile devices align with heuristics intended to reduce cognitive load and provide structure to the e-learning environment (17, 17.1, 17.2, 18, 21, 21.1).</p>
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ID	Heuristic Title:		
12	Develop and nurture networks <sup>6</sup> to support learning.		
<b>Learning Theory:</b>	Connectivism	<b>Pedagogical Area:</b>	Networked Learning Social Learning
Description:			
<p>Connectivism proposes that knowledge lies in a diversity of opinions and that this knowledge resides in a network of interconnected entities called nodes. These nodes can be almost anything with learning value, such as individuals, groups, systems, fields, ideas, or communities, but for the most part the focus lies on humans and digital resources. Although connectivism is not explicitly dependent on the Internet, the rapid growth of the web has given significant impetus to connectivism as a learning theory touted for the digital age. In its most powerful form, the connectivist network can be developed into a learning community</p>			

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<sup>6</sup> The term “network” does not necessarily indicate a computer network, but any form of network that supports learning, be it computer, social, human, etc.

that clusters together similar areas of interest and facilitates the sharing of knowledge, dialogue and other interactions that support learning.

#### Design and Evaluation Criteria:

To successfully support connectivist principles of networked learning the instructional design of the e-learning software and collaborative activities should incorporate a subset of the following guidelines:

- 1. The e-learning software should act as a focal point that recommends other learning resources (nodes on the network) through web links.** This pedagogy proposes a moderate connectivist approach in which students are assisted in identifying other learning resources. The e-learning software will act as a focal point that recommends other learning resources through web links. These links will be vetted by the software author and should be updated by teachers using the software.
- 2. The e-learning software should promote collaborative learning interactions with other students and/or teachers.** The e-learning software will act a focal point which promotes learning interactions with other students and/or teachers in an accompanying collaborative learning environment (CLE).
- 3. The learning process should be cyclical in nature.** The learning process becomes more cyclical: the learner joins the network to gather information, will make sense of the information they find, update their understanding, and will later reconnect to the network to share these realizations and new understanding. This moves the learning process from knowledge consumption to also include knowledge creation.
- 4. The e-learning software and its constituent learning objects should act as nodes on the network.** The e-learning software should be composed of SCORM (Shareable Content Object Reference Model) Learning Objects, which in themselves are learning resources on the network for students to learn from. The learning objects can be used individually or as a consolidated whole by students or reused by teachers in varying contexts to support their teaching.
- 5. The e-learning software can make use of information and other learning resources found on the network.** In accordance with connectivist approaches, the e-learning software can also make use of information and other learning resources found on the network, meaning the e-learning software will link to, stream or embed educational material from other authors (This should be within the limitations of copyright law and acknowledge the original authors).
- 6. The learning network should be developed into a learning community.** To develop the learning network into a virtual learning community requires a collaborative

learning environment (CLE) that facilitates collaborative interactions between community members. As outlined in guideline-2, there should be integration between the e-learning software and the CLE in which the e-learning software promotes collaborative learning interactions (group assignments, collaborative blogging, peer reviews, etc.) on the CLE thereby introducing the students to the learning community. However, forming and maintaining a sense of community places significant extra requirements on both teachers, those acting as facilitators, as well as the learners. These community-building activities are discussed in Appendix B.6.

#### **Educational Benefits:**

The key benefits of connectivism and use of learning networks are:

1. Students are no longer constrained by didactic teaching approaches where they are presented with the knowledge to be learned; instead, they become free to explore and assimilate learning from a variety of other resources, such as other people, web pages, blogs, educational videos, animations, simulations, etc.
2. The nodes on the network (learning resources) contain potentially differing perspectives and information that allow the students to build their knowledge actively, based on learning material that is changing and frequently updated (Heuristic 1.1).

If there is a focus on collaborative learning or the learning network is developed into a learning community then the following benefits can also be realized:

3. Communities of learning and collaborative learning, increase learning performance, improve higher-order thinking, and increase learner engagement and motivation.
4. Communities of learning increase the flow of information and [cooperation](#) among learners, their willingness to support each other, their commitment to group goals, and overall increase learner satisfaction and well-being.
5. Benefit-3 and -4 lead to an increase in learner persistence in courses and result in higher retention rates.

#### **Potential Challenges:**

Connectivist principles require significant changes in educational practice; these changes have a deep impact on both teachers and learners. The teacher now reduces their role of presenting learning material and readdresses this focus towards teaching students critical thinking and metacognitive skills for them to see connections between fields, ideas and concepts, build and cultivate their network and critically evaluate the learning material that they find. For students, the new thinking and learning skills, and additional responsibility for their own learning may initially be a challenge to some of them. It should be noted that

extreme implementations of connectivist principles or implementations which do not give due care to student support can have a negative impact on cognitive load.

Learning communities already formed at the classroom level can be readily extended into the virtual domain; however, the successful cultivation of an extended learning community spanning across classes, schools and potentially geography requires significant effort, commitment, investment and time to mature.

<b>Related Heuristics:</b>	<p>Learning networks relate strongly to social constructivist principles that individual learning is based on external knowledge and social interaction (Heuristics 8, 9, 10). They are also strongly aligned with constructivist principles since connectivism recognizes that knowledge is not simply acquired, but requires a learner to actively make sense and build knowledge from a variety of sources (Heuristics 1, 1.1, 2, 4, 6.2). Learning networks can also be used to support making thinking processes explicit, practice activities and explanatory feedback on practice activities (Heuristics 3, 7, 7.1). In addition, learning networks are also strongly related to principles of collaborative learning in which learners undertake various interactions with other individuals and groups (Heuristics 11, 11.1).</p> <p>As discussed previously, building a sense of community also has a positive influence on gamification and improves motivation by raising attention, and building relevance and satisfaction (Heuristics 14, 14.1, 14.2, 14.4, 15, 15.1, 15.2). However, connectivist principles are not appropriate for all learners (Heuristic 16.3) and should be considered with care to not negatively impact cognitive load and the structured environment of the e-learning software (Heuristics 18, 19, 21, 21.1).</p>
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ID	Heuristic Title:		
13	Use constructivist approaches to increase intrinsic motivation in the learner.		
Learning Theory:	Constructivism	Pedagogical Area:	Motivation
Description:			
<p>Intrinsic motivation stems from interest or enjoyment in the learning or the activity itself, and originates within the individual rather than relying on external incentives. Motivation is essential in giving the learner the incentive to devote the mental energy to learn. Several constructivist principles such as whole-task and problem-based learning, authentic learning,</p>			

active learning, mindful activity, etc. are shown to be intrinsically motivational and therefore supportive of the learning process.

#### Design and Evaluation Criteria:

To support intrinsic motivation the instructional design of the e-learning software and associated CLE activities should consider an appropriate subset of the following guidelines:

- 1. Focus on whole-task (holistic) learning and problem-based learning (PBL).** (Heuristics 4, 6, 6.2).
- 2. Focus on authentic educational material, examples and activities.** (Heuristics 1, 1.1)
- 3. Focus on social and collaborative learning to improve student engagement.** (Heuristics 9, 11)
- 4. Enable learners to manage and take responsibility for their own learning.** Enable learners to manage their own learning, by teaching and supporting their meta-cognitive thinking skills and then giving them responsibility for their own learning. Material that is challenging, but gives students choices, promotes perceived autonomy and self-determination positively influences motivation. (Heuristics 3, 14.3).
- 5. Convey the importance of the learning activity to the Learner.** Convey the importance of the learning activity to the learner, giving them a reason to engage and learn. In the early stages of the learning or activity, provide motivational coaching until the intrinsic motivation of the activity takes hold (Heuristic 14.2).
- 6. Focus on active learning that encourages the student to actively engage their mental processes.** Focus on active learning that encourages the student to actively engage their mental processes in practice exercises, reflective observation, theoretical conceptualization and experimentation.
- 7. Provide a problem manipulation environment that supports mindful activity.** In support of the previous point, the learner should be provided with a problem manipulation environment in which they are encouraged to manipulate, think, hypothesise and test their hypothesis.

#### Educational Benefits:

A focus on constructivist principles that increase intrinsic motivation lead to the following educational benefits:

1. A positive effect on learners' interest, engagement, and motivation.
2. Building on the increased learner motivation there is a resultant improvement in learning and academic success.

3. Learners are supported in a deeper understanding of the learning material and far transfer of knowledge.
4. Learners are more likely to persevere in difficult situations and approach demanding activities more enthusiastically than less motivated peers.
5. Related to the benefit-4 there is a decrease in dropout rates in distance learning courses from motivated learners.

**Potential Challenges:**

As discussed in previous heuristics (Heuristics 1, 4), problem-based learning and authentic learning can increase cognitive load, as such, due care should be taken in the instructional design to not overload learners.

**Related Heuristics:**

This heuristic increases intrinsic motivation by focusing on constructivist principles (Heuristics 1, 1.1, 2, 4, 5, 6, 6.2), and social and collaborative learning (Heuristics 9, 11). It aligns with approaches that focus on activities, kinaesthetic learning and making expert thinking processes explicit (Heuristic 3, 7, 7.1, 16.4). The focus on intrinsic motivation strongly aligns this heuristic with ARCS and gamification approaches (Heuristics 14, 14.1, 14.2, 14.3, 14.4, 15, 15.1, 15.2). The focus of this heuristic on social and collaborative learning should be used with consideration to learners with a read-write modal preference (Heuristic 16.3), and the focus on authentic learning and problem-based learning should be considered in relation to cognitive load (Heuristics 18, 19). Additionally, during PBL, the guided discovery inherent in this approach, must carefully consider and balance with the structured e-learning environment (Heuristics 21, 21.1).

ID	Heuristic Title:		
14	Use the concepts of Attention, Relevance, Confidence and Satisfaction (ARCS) to attain and sustain learner motivation.		
<b>Learning Theory:</b>	ARCS Motivation	<b>Pedagogical Area:</b>	Motivation
Description:			
Irrespective of the effectiveness of the learning material, without motivation, students are hampered from learning, and whilst motivation cannot be directly controlled, it can be positively influenced. According to the ARCS model, in order to predictably improve motivation and performance, the instructional material and environment should capture the			

learner’s attention, ensure relevance to the learner, build learner confidence and ensure learner satisfaction.

**Design and Evaluation Criteria:**

To successfully support ARCS motivational approaches the instructional design of the e-learning software and collaborative activities should incorporate a subset of the following guidelines:

1. 14.1: Use “Attention” grabbing strategies to increase learner motivation.
2. 14.2: Explain the “Relevance” of the learning material to increase motivation.
3. 14.3: Build “Confidence” to increase learner motivation.
4. 14.4: Build “Satisfaction” to increase learner motivation.

**Educational Benefits:**

The implementation of the ARCS model leads to the following education benefits:

1. A positive impact on learner interest, engagement, and motivation;
2. Due to increased learner motivation, a resultant improvement in learning and academic success;
3. An increased likelihood that learners will persevere in difficult situations and approach demanding activities more enthusiastically than less motivated peers;
4. A decrease in dropout rates in distance learning courses from motivated learners; and
5. The emphasis of ARCS heuristics on authentic learning, practice activities and increased learner control can also lead to deeper learning.

**Potential Challenges:**

Refer to the Potential Challenges section in the heuristics listed below.

**Related Heuristics:**

The ARCS model is implemented through the following heuristics:

- 14.1: Use “Attention” grabbing strategies to increase learner motivation.
- 14.2: Explain the “Relevance” of the learning material to increase motivation.
- 14.3: Build “Confidence” to increase learner motivation.
- 14.4: Build “Satisfaction” to increase learner motivation.

For more information on related heuristics, please refer to the relevant section in the heuristics listed above.

ID	Heuristic Title:
14.1	Use “Attention” grabbing strategies to increase learner motivation.

<b>Learning Theory:</b>	ARCS Motivation	<b>Pedagogical Area:</b>	Motivation
<b>Description:</b>			
<p>The first step in increasing learner motivation is to capture their attention and then employ strategies to sustain their attention throughout the learning process. This involves initial inquiry arousal, stimulating a deeper level of curiosity and then sustaining attention via varied instructional techniques.</p>			
<b>Design and Evaluation Criteria:</b>			
<p>The following criteria are used in the instructional design and implementation of the e-learning software and associated CLE activities:</p> <ol style="list-style-type: none"> <li>1. <b>Capture student attention at the start of the learning process.</b> This can be achieved by stimulating graphics, animations and/or instructional material that invoke: <ol style="list-style-type: none"> <li>a. A sense of wonderment, incongruity, conflict, or personal or emotional resonance with the students.</li> <li>b. An <a href="#">orienting reflex</a> based on an unexpected change or novel stimulus that attracts student attention.</li> <li>c. A <a href="#">sensation-seeking reflex</a> by stimulating the learners' inherent inclination to pursue sensory pleasure, excitement and experiences that are varied, novel, complex or intense.</li> </ol> </li> <li>2. <b>Stimulate a deeper level of curiosity by fostering the learner's inherent nature to explore, discover and understand.</b> <ol style="list-style-type: none"> <li>a. Instructional material that uses <a href="#">progressive disclosure</a> to maintain suspense and gradually build learning.</li> <li>b. Question-based techniques that prompt thinking and inquiry.</li> <li>c. Activities that create a paradox or that arouse a sense of mystery, problem-solving, or experiential situations. These, in turn, encourage a sense of inquiry and knowledge-seeking behaviour.</li> </ol> </li> <li>3. <b>Maintain attention via variable instructional design; avoid using the same instructional approaches repeatedly.</b> Instead, include variations in instructional design, presentation style and modality.</li> </ol>			
<b>Educational Benefits:</b>			
<p>Refer to the Educational Benefits section in the parent heuristic (Heuristic 14).</p>			
<b>Potential Challenges:</b>			
<p>It is important that this heuristic is implemented with careful and measured instructional design that avoids unnecessary learning material and variable instructional techniques that could, in turn, increase cognitive load.</p>			

<b>Related Heuristics:</b>	Capturing the learner’s attention is closely aligned with other heuristics in the area of motivation and gamification (Heuristics 13, 14, 14.1, 14.2, 14.3, 14.4, 15, 15.1, 15.2). Many of the techniques used to stimulate a deeper level of curiosity are based on constructivist (Heuristics 4, 6.2, 7) and social and collaborative learning (Heuristics 9, 11, 12) techniques. Additionally, multi-modal techniques can be used to maintain attention (Heuristic 16, 16.1, 16.2, 16.3, 16.4). As mentioned previously, the implementation of this heuristic must be considered in relation to avoiding unnecessary learning material or variable instructional techniques that could increase cognitive load (Heuristic 18, 19, 21, 21.1).
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<b>ID</b>	<b>Heuristic Title:</b>		
14.2	Explain the “Relevance” of the learning material to increase motivation.		
<b>Learning Theory:</b>	ARCS Motivation	<b>Pedagogical Area:</b>	Motivation
<b>Description:</b>			
To ensure that motivation is maintained the learner must perceive the learning material has a personal relevance to them; there must be a <i>“connection between the instructional environment, which includes content, teaching strategies, and social organization, and the learner’s goals, learning styles, and past experiences”</i> (Keller 2008, p.177).			
<b>Design and Evaluation Criteria:</b>			
A subset of the following criteria should be used in the instructional design and implementation of the e-learning software and associated CLE activities:			
<ol style="list-style-type: none"> <li>1. <b>Aligning with learner goals</b> - The learning material reflects an understanding of the learners’ needs and demonstrates how the new knowledge or skills will support them in achieving their goals. <ol style="list-style-type: none"> <li>a. Communicate clear learning goals that answer: Why should I learn this? What is the importance of this learning material? How can I use this new knowledge in real-life situations?</li> <li>b. Communicate how the learning material and learning goals are related to the learners’ goals.</li> <li>c. Focusing on intrinsic goal orientation in which the learners are engaged in learning that is personally interesting and freely chosen.</li> </ol> </li> </ol>			

- d. Where intrinsic goal orientation is a challenge, then extrinsic goals can be used to tie learning to an external factor such as earning a reward, passing an exam, college acceptance, etc.
- e. Ask learners to explain their own perceptions of relevance.

**2. Aligning with learning styles** - A secondary or supplementary approach in establishing relevance is related to how something is taught than to the substance of what is being taught.

- a. Using a variety of pedagogical strategies, such as individual activities and strategies that focus on cooperative group work; thereby appealing to both learners that prefer individual work and those that need affiliation.
- b. Using a multi-modal approach to appeal to the full range of modal preferences (Heuristic 16).

**3. Aligning with what is familiar** – Engage the students on a personal level and relate the learning material back to the learner’s real life.

- a. Engaging the learners on a personal level by using their names and asking them for their experience, examples and ideas.
- b. Using authentic learning approaches that connect the learning material to intrinsically interesting topics relevant to the learner’s current situation or future aspirations.

**Educational Benefits:**

Refer to the Educational Benefits outlined in the parent heuristic (Heuristic 14).

**Potential Challenges:**

With e-learning software, as opposed to a classroom environment where the teacher is dynamically interacting with students, there is an increased challenge in building a personalised learning profile of the learner’s individual goals and motives. As such, the learning profile is typically generalised based on the target audience and the learner analysis undertaken at the start of the motivational design process.

**Related Heuristics:**

Establishing the relevance of the learning material is closely aligned with other heuristics in the area of motivation and gamification (Heuristics 13, 14, 14.1, 14.2, 14.3, 14.4, 15, 15.1, 15.2). Explaining the relevance of learning material to students offers foundational support in many of the approaches outlined in this pedagogy. At a fundamental level, this heuristic builds upon authentic learning (Heuristics 1, 1.1). It then uses social and collaborative learning, connectivist principles and multi-modal learning to help align with the learner’s learning style

	(Heuristics 9, 11, 12, 16, 16.1, 16.2, 16.3, 16.4). However, due care should be taken to not give excessive focus on authenticity and relevancy at the expense of the instructional goals (Heuristic 18).
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ID	Heuristic Title:		
14.3	Build “Confidence” to increase learner motivation.		
<b>Learning Theory:</b>	ARCS Motivation	<b>Pedagogical Area:</b>	Motivation
Description:			
<p>Building learners’ confidence in their ability to learn also increases their motivation to learn; any learned helplessness or fear of the topic, skill or environment that hinders learning should be addressed and replaced by an expectation of success. The positive expectancy for success should then be followed promptly by actual success that the learners can clearly attribute to their own abilities and efforts.</p>			
Design and Evaluation Criteria:			
<p>A subset of the following criteria is followed in the instructional design and implementation of the e-learning software and associated CLE activities:</p> <ol style="list-style-type: none"> <li><b>1. Establish trust and positive expectations for learning success:</b> <ol style="list-style-type: none"> <li>a. Inform the learners of what is expected of them by explaining the requirements for success and the evaluation criteria.</li> <li>b. Address any fear or anxiety held by the learners.</li> <li>c. If using a progressive disclosure strategy, the above points will need to be softened in order not to remove suspense.</li> <li>d. Provide ongoing encouragement to complete the lesson.</li> </ol> </li> <li><b>2. Provide opportunities for meaningful success:</b> <ol style="list-style-type: none"> <li>a. Opportunities for success should be provided as soon as possible in the lesson.</li> <li>b. Meaningful success is contingent on there being enough challenge to require a degree of effort to succeed, but not so much that it creates serious anxiety.</li> <li>c. The success must be clearly attributable to the learner’s efforts and ability rather than to luck or the task being too easy.</li> <li>d. If the learning material is new, the level of challenge should be relatively modest and combined with frequent feedback that confirms the learner’s success or helps the learner progress towards success.</li> <li>e. When the basics are mastered, progress to higher levels of challenge that help learners exercise and sharpen their skills.</li> </ol> </li> </ol>			

- f. Pacing should be adjusted as competency levels change; typically, success activities should move quickly from simple to complex, or known to unknown, to avoid boredom, but not so quickly that learners become anxious.

**3. Balance a stable e-learning environment with the learner’s need to feel in control and responsible for their success:**

- a. Provide a stable learning environment that sets the standards expected and guides the learning experience.
- b. Within that stable learning environment, allow the learners as much personal control (as possible) over their actual learning experience. Techniques that support such personal control are:
  - i. Foster an environment where it is ok to make mistakes and learn from them.
  - ii. Use learning activities and problem-based methods that require the learner to exercise personal control and judgement to solve.
  - iii. Provide corrective feedback that helps the learner see the cause of their mistake and allows them to learn and retry.

**Educational Benefits:**

Refer to the Educational Benefits section in the parent heuristic (Heuristic 14).

**Potential Challenges:**

E-learning software used in isolation, without teacher involvement, cannot adequately address learners’ fear and anxieties. Furthermore, the instructional design of the e-learning software will require careful balance in the following areas:

- The guideline to explain to learners the learning outcomes, requirements for success and the evaluation criteria may need to be mitigated when using progressive disclosure techniques and problem-based learning (Heuristic 4).
- The criteria related to giving learners personal control in their learning needs to be balanced against the provision of a stable learning environment (Heuristics 21, 21.1).
- The provision of success opportunities creates a challenge to move quickly enough to avoid boredom, but not so quickly that learners become anxious.

**Related Heuristics:**

Building confidence in the learner is closely aligned with other heuristics in the area of motivation and gamification (Heuristics 13, 14, 14.1, 14.2, 14.3, 14.4, 15, 15.1, 15.2). This heuristic focuses strongly on practice activities, explanatory feedback, worked-examples, scaffolding and managing the level of challenge (Heuristics 4.1, 7, 7.1, 8, 10). Although the personal control implicit in guided discovery is important

	(Heuristic 4), more emphasis should be placed on the provision of a stable e-learning environment (Heuristics 21, 21.1).
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ID	Heuristic Title:		
14.4	Build “Satisfaction” to increase learner motivation.		
Learning Theory:	ARCS Motivation	Pedagogical Area:	Motivation
Description:			
Once motivation is inspired in the learner, it needs to be maintained by providing the learner with a sense of satisfaction with the process and/or results of the learning experience. This is achieved by a combination of intrinsic methods, extrinsic reinforcement and a sense of fairness in the learning results.			
Design and Evaluation Criteria:			
A subset of the following criteria should be followed in the instructional design and implementation of the e-learning Software and associated CLE activities:			
<ol style="list-style-type: none"> <li><b>1. Use intrinsically motivational learning experiences.</b> <ol style="list-style-type: none"> <li>a. Provide meaningful opportunities for learners to use their newly acquired knowledge and skills. These opportunities typically have the following characteristics:               <ol style="list-style-type: none"> <li>i. They are authentic problems, simulations, or worked-examples that allow learners to apply what they have learnt and help to transfer from classroom to real-life.</li> <li>ii. They focus on providing the learner with the intrinsic satisfaction that they have mastered the learning.</li> <li>iii. They are typically scheduled towards the end of the lesson or the course.</li> </ol> </li> <li>b. Provide opportunities for learners to coordinate, collaborate, and interact with other learners.</li> <li>c. Provide opportunities for learners to have their views heard and respected.</li> <li>d. Encourage in learners a sense of control over their learning experience.</li> <li>e. Support learners in seeing how the various pieces of the learning experience fit together holistically.</li> </ol> </li> <li><b>2. Provide positive extrinsic reinforcement to learners’ successes.</b> <ol style="list-style-type: none"> <li>a. Extrinsic reinforcement can be used to supplement, but not replace, intrinsic motivational approaches, both should be used in combination.</li> </ol> </li> </ol>			

<p>b. Extrinsic reinforcement includes the use of opportunities for advancement, verbal praise, certificates, and any real or symbolic rewards and incentives that provides external recognition of achievement.</p>	
<p><b>3. Ensure learners perceive the learning process, assessment and rewards as being fair.</b></p>	
<p>a. Ensure that course outcomes are consistent with the initial presentation of course purpose and expectations.</p>	
<p>b. Assessment results and extrinsic reinforcements are not seen in isolation or in terms of absolute value. They need to be consistent, commensurate with the efforts expended in the learning, and comparatively fair in relation to learning peers.</p>	
<p><b>Educational Benefits:</b></p>	
<p>Refer to the Educational Benefits section in the parent heuristic (Heuristic 14).</p>	
<p><b>Potential Challenges:</b></p>	
<p>With reference to guideline-1.b, as noted in heuristic 11, collaborative activities are not appropriate in all circumstances and therefore should not be considered to always lead to increased satisfaction.</p>	
<p><b>Related Heuristics:</b></p>	<p>Building learner satisfaction is closely aligned with other heuristics in the area of motivation and gamification (Heuristics 13, 14, 14.1, 14.2, 14.3, 14.4, 15, 15.1, 15.2). It builds upon authentic learning, problem-solving , activities and providing learners with a challenge (Heuristics 1, 1.1, 4, 4.1, 5, 6.2, 7, 7.1, 8, 10). It also builds upon social and collaborative learning, and connectivist principles (Heuristics 9, 11, 11.1, 12). However, caution should be taken that the focus on authentic learning, challenging problems and increased personal control for learners does not negatively impact cognitive load or undermine the structured e-learning environment (Heuristics 18, 19, 21, 21.1).</p>

<b>ID</b>	<b>Heuristic Title:</b>		
15	Use gamification to increase motivation and learning performance.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	Gamification Motivation
<b>Description:</b>			

In the context of e-learning, gamification is the use of game design elements within e-learning software to increase the pleasure, fun, and motivation in the learning process and to encourage positive learning behaviour. Game design elements must be tightly integrated with existing intrinsically motivational aspects of the software. Suggested game design elements include: points, leaderboards, achievements/badges, levels, rewards, progression, challenge, storytelling, clear goals, rapid feedback, explanatory feedback, freedom to fail, etc.

#### Design and Evaluation Criteria:

The implementation of gamification can be broadly split into two high-level guidelines that are discussed in detail as separate sub-heuristics:

1. **15.1: Integrate gamification elements tightly with existing learning processes.**
2. **15.2: Build extrinsic gamification elements on top of existing learning processes.**

#### Educational Benefits:

The overriding benefit of gamification is to create a gameful and playful learning experience that motivates the intended learning behaviour, and generally, increases the joy of learning. Gamification attempts to build upon social psychological processes such as self-efficacy, group identification, and social approval to provide learning rewards that motivate continued good work.

Gamification arguably provides positive effects on motivation and ultimately on learning. However, the findings from previous studies have some variation in results and some shortcomings in research design that leave them open to some doubt.

#### Potential Challenges:

Current implementations of gamification often focus too heavily on the points and rewards systems from games (guideline-2) and ignore intrinsically motivational aspects (guideline-1). This approach can in fact be detrimental to the learning process by reducing the learner's own internal motivation. Furthermore, it is postulated that once applied, the removal of such gamification elements may have a detrimental effect due to the loss of earned badges and points and the dependency on external motivators. Additionally, there is concern that the positive results of gamification may not be long-term and are in fact caused by a novelty effect.

#### Related Heuristics:

This heuristic is implemented through the following two sub-heuristics:

- 15.1: Integrate gamification elements tightly within existing learning processes.
- 15.2: Build extrinsic gamification elements on top of existing learning processes.

	Refer to the Related Heuristics sections of the above sub-heuristics for more information.
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ID	Heuristic Title:		
15.1	Integrate gamification elements tightly within existing learning processes.		
Learning Theory:	None	Pedagogical Area:	Gamification Motivation
Description:			
<p>Many aspects of good game design correlate with existing pedagogical practices; therefore, they should already exist within the instructional design of the e-learning software. These should not be reinvented for gamification purposes; instead, gamification elements should simply integrate with the existing pedagogical elements. These pedagogical elements include: storytelling, progressive challenge, intrinsically motivational activities, rapid explanatory feedback, tutorials on how to use (play), and social interaction.</p>			
Design and Evaluation Criteria:			
<p>Gamification elements can be implemented in the e-learning software and CLE activities by integrating the following pedagogical heuristics:</p> <ol style="list-style-type: none"> <li>1. <b>Gamified learning should offer progression and progressive challenge.</b> As with all good games, there needs to be progression and progressive challenge as the learner moves from novice to expert and eventually to master. The level of challenge needs to be enough to avoid boredom, but not so much that it causes frustration or demotivation (Heuristics 8, 10, 14.3 guideline-2, 14.4 guideline-1).</li> <li>2. <b>Gamified learning should offer an engaging story.</b> As with all good games, there needs to be a surrounding story and narrative that the player can engage in. Likewise people learn better when the educational material is embedded in a story they can relate to. A unifying story should be used throughout a curriculum to put learning into a realistic context in which actions and tasks can be practised (Heuristics 1, 1.1, 4, 6.2, 14.1 guideline-2, 14.2 guideline-3).</li> <li>3. <b>Gamified learning should allow learners the freedom to fail and provide rapid feedback to support learning.</b> Games offer a fictional environment in which various game cues provide players with continuous feedback on how they are doing, and when they make a mistake, they are not excessively penalised, they merely lose a life or start at the last completed level, etc. Feedback is already an essential part of education, but in particular, the kind of continuous and rapid feedback used in games</li> </ol>			

has direct pedagogical links to formative assessment in which the learner receives ongoing assessment and feedback that is separated from permanent marks. By removing the fear of grades, learners are encouraged to explore and take risks in their learning without fear of reproach (Heuristics 7, 7.1, 14.3 guideline-3).

4. **Gamified learning should provide activities for learners to engage in.** Gamers are not passive consumers of a game they are actively engaged in the game; each step and each decision make a difference in the game. Likewise, constructivist principles promote active learning in which the learner builds their knowledge through mindful activity (Heuristics 13 guideline-6, 4, 4.1, 6.2, 7, 7.1, 14.3 guideline-2, 14.4 guideline-1).
5. **Game rules and tutorials need to be explained to the players.** All games have an associated set of rules, which need to be explained to the players, and depending on the complexity of the game, these are also supplemented by hints, tutorials, training missions and guides which help the players advance in the game. In gaming parlance, this is called novice onboarding. Likewise in education, students need to be advised what the intended learning outcomes are and more specifically for e-learning, to have some training or guidance on how to use the e-learning software (Heuristics 3 guideline-2, 11 guideline-4, 14.2 guideline-1, 14.3 guideline-1).
6. **Gamified learning is a social activity.** Gaming is typically a social activity that revolves around competition or cooperation with other players. Competition often takes the form of challenging, taunting, bragging, etc. and cooperation can take the form of greeting, sharing, helping and gifting etc. Kim (2011), subdivides gamers into four main groups: Killers, Achievers, Explorers and Socializers and then maps their social actions accordingly. Refer to [Figure 64](#).

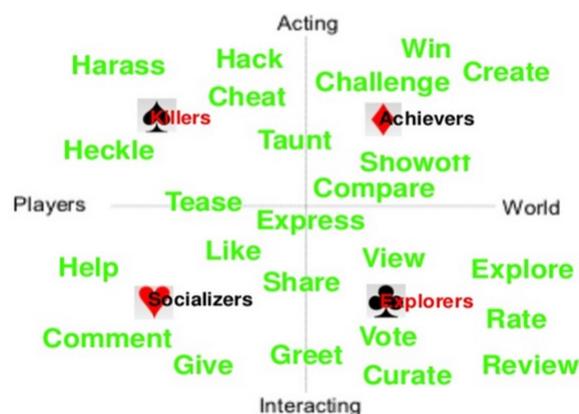


Figure 64: Social actions drive social engagement.

(Kim 2011, p.119)

A significant subset of the aforementioned social actions should be supported by the e-learning software or the collaborative learning environment. However, considering the pedagogical focus on high-school learning, the negatives social actions in the top left quadrant of the graph should be heavily deemphasised or not supported. This pedagogy supports collaborative and social interaction through the following existing heuristics 9, 11, 11.1, 12.

**Educational Benefits:**

Please refer to the Educational Benefits section in heuristic 15 and the Educational Benefits in the heuristics listed in the Design and Evaluation Criteria section directly above.

**Potential Challenges:**

Refer to the Potential Challenges in the heuristics listed in the Design and Evaluation Criteria section.

**Related Heuristics:**

This heuristic reflects that many gamification elements are already supported by modern pedagogical practices. An engaging story is provided by authentic learning and problem-based learning approaches (Heuristics 1, 1.1, 4, 6.2, 14.1 guideline-2, 14.2 guideline-3). Progression and progressive challenge are provided by targeting the ZPD, offering scaffolding, and setting the level of challenge according to progression within the learning material (Heuristics 8, 10, 14.3 guideline-2, 14.4 guideline-1). Having activities for learners to engage in is provided by problem-based learning, practice activities and worked-examples; these are also used as a basis to support rapid feedback and the freedom to fail (Heuristics 13 guidelines 5 and 6, 4, 4.1, 6.2, 7, 7.1, 14.3 guideline-2, 14.4 guideline-1). The social aspect of gamified learning is supported by social and collaborative learning, and connectivist principles (Heuristics 9, 11, 11.1, 12). The need to explain game rules is supported by clearly setting learning outcome, setting structure, instructions and processes for activities, especially collaborative activities, and making thinking processes explicit (Heuristics 3 guideline-2, 11 guideline-4, 14.2 guideline-1, 14.3 guideline-1). The implementation of gamified learning is aligned with multi-modal approaches, visualisation and using a more informal conversational style (Heuristics 16, 16.1, 16.2, 16.3, 16.4, 20).  
The combination of all the above approaches supports the integration of e-learning into long-term memory and support intrinsic motivation

(Heuristics 5, 13, 15, 15.1). However, caution should be taken that the focus on authentic learning and challenging problems does not negatively affect cognitive load (Heuristics 18, 19).

ID	Heuristic Title:		
15.2	Build extrinsic gamification elements on top of existing learning processes.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	Gamification Motivation
<b>Description:</b>			
<p>Certain gamification elements are not part of established pedagogical approaches; they attempt to leverage people’s love of competition and reward to encourage desired learning behaviour. They reflect learner progress and attempt to motivate desired learning behaviour through extrinsic rewards such as points, leaderboards, achievements/badges and levels. Since these gaming elements are not inherently part of existing pedagogical practices, they need to be built on top; however, they should only be used if there is an existing foundation in heuristic 15.1.</p>			
<b>Design and Evaluation Criteria:</b>			
<p>To implement gamification elements that focus on extrinsic reward, the instructional design of the e-learning software and CLE activities must consider a significant subset of the following guidelines:</p> <ol style="list-style-type: none"> <li>1. <b>Encourage desired learning behaviour with instant reward.</b> In gamification terms, this is called feedback mechanics and is designed to give immediate positive feedback (reward) that makes the player feel good about completing something and motivate them to continue with the desired behaviour. This is achieved by the following mechanisms: <ol style="list-style-type: none"> <li>a. <b>Points are a quantifiable metric</b> that track and define progress; they are awarded for undertaking some action or completing some activity. Typical examples include: <ol style="list-style-type: none"> <li>i. <b>Experience points</b> are earned directly via the player's actions and are used to track and reward progress or certain activities.</li> <li>ii. <b>Redeemable points</b> are similar to experience points but can also be “cashed in” to purchase virtual or real goods or services.</li> <li>iii. <b>Skill points</b> are earned by interacting with the game and reflect mastery of an activity.</li> </ol> </li> </ol> </li> </ol>			

iv. **Social Points** are earned by undertaking socially valuable contributions and actions; they are used to track the social reputation or influence of a player.

b. **Badges are usually awarded** for actions a **player has just completed**. Badges offer a more visual display of achievement than points and can be shown on profile pages or user accounts.

**2. Communicate progress to the learner.**

a. Learner progress can be reflected back to the learner via a combination of gamification mechanisms such as points, badges, a progress bar and levels.

b. Games are typically segmented into levels of increasing difficulty; likewise, levels can be built into the e-learning software. Level completion marks progress but also reflects achievement and status.

**3. Provide social recognition for desired learning behaviour.** Social recognition can be given to learners by integrating with social media platforms or in this instance giving social recognition within the collaborative learning environment (learning community). This can be achieved by showing points, levels and badged on user profiles or by leaderboards that showcase the most skilled and devoted learners.

**Implementation Tips:**

It is critical for the success of gamification elements such as points and badges that they are triggered by actions that have a genuine pedagogical value such as mastering a new skill, reviewing optional learning material, successfully undertaking a higher-level challenge or quiz, or supporting peers in their learning etc.

The trigger actions should not overly focus on areas with limited pedagogical value, such module completion dates, early completion of modules or number of modules completed.

In addition, the granularity of trigger actions should be sufficiently detailed in order to focus on specific quizzes, challenges or actions and not on entire modules.

Extrinsic gamification elements are typically implemented within the Learning Management System (LMS); therefore it is crucial that the school's LMS is evaluated to identify whether it supports the planned gamification strategy. If it does not support gamification or offers limited support to crucial aspects of the gamification strategy, then consider not implementing gamification or implementing it in an unplugged manner, outside of the LMS.

**Educational Benefits:**

Please refer to the Educational Benefits section in heuristic 15.

<b>Potential Challenges:</b>	
<p>Refer to the Potential Challenges section in heuristic 15.</p> <p>As discussed in the potential challenges in heuristic 15 the removal of gamification rewards can have a detrimental effect, therefore it is important that a long-term gamification strategy is defined. As discussed in the implementation tips, this gamification strategy must be evaluated in conjunction with the LMS support for gamification to ensure they are aligned, offer the right level of granularity, and can reward student actions that have genuine learning value.</p>	
<b>Related Heuristics:</b>	<p>The provision of extrinsic reward and social recognition offers modest support for a number of heuristics in this pedagogy. But offers direct support for problem-solving and practice activities (Heuristics 4, 7) and heuristics in the area of motivation and gamification; it does this by building on top of intrinsically motivational approaches a layer of extrinsic reward (Heuristics 13, 14, 14.1, 14.2, 14.3, 14.4, 15, 15.1, 15.2). The provision of social recognition to learners is supported by social and collaborative learning, and connectivist principles (Heuristics 9, 10, 11, 11.1, 12). The provision of badges is inherently a visual approach which aligns with visual modal preferences (Heuristic 16.1). Additionally, gamification involves the use of a more informal style (Heuristic 20). Representing progress or giving reward based on game levels is supported by the approach of segment learning (Heuristic 19).</p>

<b>ID</b>	<b>Heuristic Title:</b>		
16	Use multi-modal learning approaches.		
<b>Learning Theory:</b>	VARK Learning Styles	<b>Pedagogical Area:</b>	Multi-Modal Learning
<b>Description:</b>			
<p>Students are not restricted to only one of the modal preferences (visual, aural, read-write, or kinaesthetic). It is typical for students to exhibit a preference for one particular mode, and a relative weakness or strength in some other modes. However, it must be recognised that even the relatively weaker modes cannot be ignored; even if a student has a strong preference on a particular modality, they should still be exposed to diverse learning experiences and encouraged to develop into more versatile learners. The e-learning software should accommodate the four modalities by providing a variety of different learning options that consider the different learning styles. By combining a mixture of approaches, the students are</p>			

given the possibility to choose the instructional style that best fits their own individual learning style(s).

#### Design and Evaluation Criteria:

To implement multi-modal learning, the instructional design of the e-learning software and CLE activities must consider a significant subset of the following guidelines:

1. **The e-learning software and associated CLE activities incorporate learning material that supports the four VARK modal preferences.** The approaches and activities appropriate for each modal preference are outlined in the following heuristics.
  - 16.1: Support visual modal preference.
  - 16.2: Support aural modal preference.
  - 16.3: Support read-write modal preference.
  - 16.4: Support kinaesthetic modal preference.
2. **The e-learning software and associated CLE activities should provide an approximate balance between the four modal preferences.**
3. **The choice and balance of modal channels must carefully consider and align with the learning context and content.** Not all modal channels are appropriate or optimal for conveying specific learning material.
4. **The e-learning software and associated CLE activities should support the four modal preferences without causing cognitive overload to the students.**

#### Educational Benefits:

1. Knowledge of learning styles and adjusting instructional approaches and resources to complement them is shown to increase learning performance.
2. The communication of learning material via multiple modalities provides increased support for learners to understand and assimilate the learning into existing schemas in long-term memory (deep learning).
3. Giving focus or at least options for students to learn via their preferred perceptual mode increases their motivation.
4. Exposing students to learning material across the modalities and encouraging their learning development can enable students to become more versatile learners.
5. The underlying nature of certain concepts and even certain subjects make different modalities more appropriate in their teaching.

#### Potential Challenges:

This approach must be mitigated by a consideration of cognitive load; students do not have infinite working memory or cognitive capacity. It is important not to overload the students with too many competing channels of learning communication. The instructional design of

the e-learning software must ensure that students do not feel pressured to try to take in information from all the modal channels or worse to take them in and try to compare them.

<b>Related Heuristics:</b>	Multi-modal learning is implemented via adherence to the following sub-heuristics on visual, aural, read-write and kinaesthetic learning (Heuristics 16.1, 16.2, 16.3, 16.4). It provides underlying support for a number of heuristics in this pedagogy and strong support for practice activities, building motivation through attention and relevance and gamification (Heuristics 7, 14, 14.1, 14.2, 15, 15.1, 15.2). Multi-modal learning aligns well with the multimedia and communication capabilities of mobile devices (Heuristic 11.1). Multi-modal approaches can help reduce cognitive load by presenting visual and aural material together (Heuristics 17, 17.1), but can also negatively affect cognitive load by overloading visual channels or including material not directly relevant to instructional goals (Heuristics 17.2, 18).
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ID	Heuristic Title:		
16.1	Support visual modal preference.		
Learning Theory:	VARK Learning Styles	Pedagogical Area:	Multi-Modal Learning
Description:			
Visual learners prefer graphical and symbolic ways of representing information. They have good visual recall and prefer information to be presented visually, in the form of diagrams, graphs, maps, posters, displays, etc. In addition, where learning material is complex, includes invisible or difficult to see phenomena, or has difficult concepts or process steps, then special attention must be given to visualization tools that help learners to construct appropriate mental images and visualize activities.			
Design and Evaluation Criteria:			
The instructional design and implementation of the e-learning software and collaborative learning activities should support an appropriate subset of the following.			
<b>1. Learning material that is rich in visual depictions</b> such as:			
a) Diagrams	b) Maps	c) Mind-maps	
d) Posters	e) Graphs	f) Displays	
g) Flowcharts	h) Multimedia	i) Symbolic representations	
j) Graphical organisers	k) Visual demonstrations	l) Visual modelling	

2. **Represent thought processes as visual representations.**
3. **Focus on the big picture with holistic instead of reductionist approaches.**
4. **Use underlining, highlighters and different colours.**
5. **Link text with associated diagrams and pictures.**
6. **Use non-visual learning that is appealing to visual learners:**
  - a. Provide past examples of finished products.
  - b. Activities that allow freedom and emphasise creativity.
  - c. Group learning.
  - d. Role-playing.
7. **Avoid over focus on word usage, syntax and grammar.**
8. **Promote activities to convert notes into one-page pictures and vice versa.**
9. **Provide the opportunity for students to use diagrams and visual elements in answering questions and in assignments.**
10. **Support visualization by including visual representations of learning material that is very complex, includes invisible or difficult to see phenomena, or has difficult concepts or process steps.** The e-learning software should include the appropriate use of task or domain specific images, animations, simulations, static frames and video to enable students to visualise learning material.

#### **Educational Benefits:**

Refer to the Educational Benefits section in the parent heuristic (Heuristic 16).

In addition, with regards guideline-10, embodying learning material according to visualization approaches optimises essential processing by reducing the complexity of the learning material and presenting it in a way that is easier for the learner to assimilate. Furthermore, it helps in building accurate mental schemas that can be integrated with existing knowledge, thereby maximising germane cognitive processing.

#### **Potential Challenges:**

Refer to the Potential Challenges section in the parent heuristic (Heuristic 16).

#### **Related Heuristics:**

Refer to the Related Heuristics section in the parent heuristic (Heuristic 16).

In addition, this heuristic gives greater support to extrinsic gamification approaches (Heuristic 15.2) and with regards guideline-10, if visualization approaches are adopted then a positive relationship is drawn with making thinking processes explicit and building mental schemas that integrate with existing knowledge (Heuristics 3, 5).

ID	Heuristic Title:		
16.2	Support aural modal preference.		
Learning Theory:	VARK Learning Styles	Pedagogical Area:	Multi-Modal Learning
Description:			
<p>Auditory learners prefer to learn from listening. They have good auditory memory and benefit from lectures, tutorials, discussions with other students and faculty, interviewing, hearing stories, audio tapes, etc.</p>			
Design and Evaluation Criteria:			
<p>The instructional design and implementation of the e-learning software and collaborative learning activities should support an appropriate subset of the following:</p> <ol style="list-style-type: none"> <li>1. <b>Give additional focus to auditory learning material.</b></li> <li>2. <b>Promote lectures and tutorials that are primarily focused around hearing the teacher talk.</b></li> <li>3. <b>Emphasise oral presentation, instructions, questioning, answers and reward.</b></li> <li>4. <b>Promote discussion activities with other students and/or teacher.</b></li> <li>5. <b>Promote activities to orally describe overheads, pictures and other visuals to somebody else.</b></li> <li>6. <b>Promote activities to record interesting examples, stories and jokes as memory aids.</b></li> <li>7. <b>Promote activities to create audio versions of instructional texts and learner notes.</b></li> <li>8. <b>Promote activities to interview experts.</b></li> <li>9. <b>Promote activities to read written notes aloud.</b></li> <li>10. <b>Promote activities to supplement existing written notes by talking with others and collecting notes from the textbook or other learning resources.</b></li> <li>11. <b>Promote activities to orally report your understanding of a topic or explain your notes to another aural person.</b></li> </ol>			
Implementation Tip:			
<p>Audio recording and playback have become quite an easy activity using an audio player/recorder or via the vast majority of mobile phones and computers. Likewise, there is a large number of audio/video streaming and chat software that can be used for lectures, tutorials and discussions. The aural approaches outlined can be used in face-to-face activities or implemented in the e-learning software or through pedagogically appropriate activities in the collaborative learning environment. However, it is important that the e-learning software gives support to either enable / disable audio and remains pedagogically effective even when audio is disabled.</p>			

<b>Educational Benefits:</b>	
Refer to the educational benefits section in the parent heuristic (Heuristic 16).	
<b>Potential Challenges:</b>	
<p>The recording of audio has become a relatively simple activity, but it still may require additional support from teachers to educate students and potentially to give student access to audio recording equipment.</p> <p>Audio recording and playback activities are complicated by a shared classroom environment and noise overlap between students. This can be partially mitigated by headphones, but this, in turn, becomes an additional hardware resource necessary to support the e-learning software.</p> <p>In addition, please refer to the potential challenges outlined in the parent heuristic (Heuristic 16).</p>	
<b>Related Heuristics:</b>	<p>Refer to the Related Heuristics section in the parent heuristic (Heuristic 16).</p> <p>In addition, this heuristic should be considered in relation to heuristic 20 which gives guidance on how audio narration should have a conversational style.</p>

<b>ID</b>	<b>Heuristic Title:</b>		
16.3	Support read-write modal preference.		
<b>Learning Theory:</b>	VARK Learning Styles	<b>Pedagogical Area:</b>	Multi-Modal Learning
<b>Description:</b>			
Read-write learners prefer to learn through information displayed as words; they benefit from lecture notes, note taking, journals, lists, definitions, textbooks, etc.			
<b>Design and Evaluation Criteria:</b>			
The instructional design and implementation of the e-learning software and collaborative learning activities should support an appropriate subset of the following:			
<ol style="list-style-type: none"> <li>1. <b>Give increased focus on individual learning.</b></li> <li>2. <b>Avoid vague, non-specific activities in favour of giving more concrete direction on expectations and deliverables.</b></li> <li>3. <b>Provide written learning material (lecture notes, handouts and references to textbook and manuals)</b></li> <li>4. <b>Use lists, headings, glossaries and definitions.</b></li> <li>5. <b>Promote the use of:</b> <ol style="list-style-type: none"> <li>a. Written directions.</li> <li>b. Written questions.</li> </ol> </li> </ol>			

- c. Well-structured open-ended questions with a text response.
- d. Essay writing activities.
- e. Journaling activities
- f. Word walls activities (wordle).

**6. Allocate reading time.**

**7. Promote activities to write notes, then rewrite and reread repeatedly as a revision tactic.**

**8. Promote activities to rewrite subject ideas and principles into different words.**

**9. Promote activities to reconstruct any visual elements such as diagrams, graphs, charts etc. into textual statements.**

**10. Promote activities to reconstruct actions, events or behaviours into textual statements.**

**11. Promote activities to arrange learning material and notes into titles, hierarchies and points.**

**12. Promote activities to represent list-based learning material into multiple-choice questions.**

**Implementation Tip:**

The above guidelines can all be implemented via the appropriate design and implementation of the e-learning software and CLE activities; specifically, the use of note apps, e-portfolios, cloud-based word processors, Wikis, blogging, journals and text chats.

**Educational Benefits:**

Refer to the Educational Benefits section in the parent heuristic (Heuristic 16).

**Potential Challenges:**

Read-write learners often prefer individual learning, so less focus should be given to group and collaborative learning; however, the CLE can still be used for activities such as Wikis, blogging, journals and text chats.

As discussed in heuristic 17.1, avoid the overuse of text. Long passages and too much text can become discouraging for many learners. Please refer to Appendix B.9 for some tips on how to reduce unnecessary text.

In addition, please refer to the Potential Challenges section in the parent heuristic (Heuristic 16).

**Related Heuristics:**

Refer to the Related Heuristics section in the parent heuristic (Heuristic 16).

	<p>In addition, it should be noted that learners with a read-write preference are potentially less receptive to social and collaborative learning (Heuristics 9,11, 12, 13 guideline-3).</p> <p>In addition, this heuristic should be considered in relation to heuristic 20 which gives guidance on how text material should be written in a conversational style and heuristic 17.1 which recommends not to overuse text.</p>
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ID	Heuristic Title:		
16.4	Support kinaesthetic modal preference.		
Learning Theory:	VARK Learning Styles	Pedagogical Area:	Multi-Modal Learning
Description:			
<p>Kinaesthetic learners prefer learning that connects to their experience and reality. They are more adept at recalling events and associated feelings or physical experiences from memory. This experience can be derived through physical activity such as field trips, manipulating objects and other practical first-hand experience. However, it can also be derived through simulation and the presentation of information strongly tied to experience and reality. Hence, Kinaesthetic learning can be multi-modal since the information describing experience and reality can be presented in a visual, aural or read-write form.</p>			
Design and Evaluation Criteria:			
<p>The instructional design and implementation of the e-learning software and collaborative learning activities should support an appropriate subset of the following:</p> <ol style="list-style-type: none"> <li>1. <b>Promote practical activities (experiments) either real or simulated that engage understanding by doing</b>, i.e. by manipulating objects, building or constructing, or hands-on projects.</li> <li>2. <b>Promote learning material directly connected to experience and reality.</b></li> <li>3. <b>Promote learning based on real-life examples.</b></li> <li>4. <b>Provide case studies and real-life applications to help with the understanding of principles and abstract concepts.</b></li> <li>5. <b>Provide questions based on practical activities.</b></li> <li>6. <b>Provide learning based on live demonstrations.</b></li> <li>7. <b>Promote activities focused on finding solutions to real-life problems.</b></li> <li>8. <b>Promote activities that incorporate an element of trial and error.</b></li> <li>9. <b>Provide learning material that uses exhibits, samples, pictures and photographs that illustrate an idea and tie back to real life.</b></li> </ol>			

- 10. Promote activities to recall experiments and physical experiences from memory.
- 11. Promote learning that uses multiple senses, such as sight and hearing or tries to evoke the senses of touch, taste and smell.
- 12. Promote activities that use previous exam papers and conditions.

**Educational Benefits:**

Refer to the Educational Benefits section in the parent heuristic (Heuristic 16).

**Potential Challenges:**

It is important to reaffirm that although kinaesthetic learners learn from real-life and personal experience and find great value in physical activity, they still derive significant learning value from simulations and other learning that is directly linked to reality or experience. The kinaesthetic learner cannot physically experience everything, what is important is that the sense of experience and reality is conveyed to them. The latter can be aptly provided by educational technology.

In addition, please refer to the Potential Challenges section in the parent heuristic (Heuristic 16).

**Related Heuristics:**

The successful implementation of kinaesthetic learning builds upon authentic learning, problem-based learning, practice activities and the use of visualisation (Heuristics 1, 4, 6.2, 7, 13-guidelines 2 and 7). In addition, please refer to the Related Heuristics section in the parent heuristic (Heuristic 16).

ID	Heuristic Title:		
17	Integrate words and graphics together, instead of words alone.		
<b>Learning Theory:</b>	Cognitive Theory	Load	<b>Pedagogical Area:</b> Reducing cognitive load
<b>Description:</b>			
An essential part of active processing is to construct visual and text representations of learning material and to connect them mentally. The e-learning software should, therefore, include both words (audio or screen text) and graphics (static illustrations, animations or videos) to support learners in developing their mental models. The visual elements should not be treated as an afterthought after the text has been written; instead, multimedia lessons should contain words and corresponding visuals that work together to explain the learning material.			

### Design and Evaluation Criteria:

The integration of words and graphics together to support learning is commonly known as the

multimedia principle; in order to support multimedia learning the e-learning software and collaborative activities should consider the following guidelines:

- 1. Visual elements should be integrated with accompanying aural or printed text.** Illustrations, diagrams, photographs, maps, concept-maps, charts and graphs, animations, videos, etc. can all be integrated into the e-learning software with accompanying aural or printed text.
- 2. A variety of graphical types can be used in accordance with the intended learning outcomes.** The visual elements must be designed in consideration of cognitive processes for deep learning and represent the key information and relationships in the learning content. There are the following graphical types: representative, organisational, relational, transformative, interpretative and decorative. Each one can be used in a different learning context; typically, the only one to be avoided is decorative graphics. For a brief description of these graphical types, please refer to Appendix B.7.
- 3. Graphical elements should be used to provide navigational support and signposts for learning.** Graphics can be integrated with text to provide a lesson interface. The e-learning software must provide a uniform and consistent Graphical User Interface (GUI) that supports learning. This is discussed in depth in heuristic 21.1.

### Educational Benefits:

The implementation of the multimedia principle as compared with learning from words only leads to the following education benefits:

1. Improved learning performance,
2. A deeper understanding in which knowledge is encoded and remembered better,
3. It is particularly relevant for scientific and technical learning that can be complex and as such is appropriate for the computer science discipline, and
4. It is especially important for novice learners (with low domain knowledge), who are less experienced in creating their own mental images.

### Potential Challenges:

It should be noted that decorative graphics, which are added just for aesthetic appeal or humour should be avoided since they add extraneous cognitive load without promoting learning.

<b>Related Heuristics:</b>	<p>Integrating words and graphics together offers moderate support for a number of heuristics in the pedagogy. In particular, the increased efficiency in cognitive processing enables more challenging learning material (Heuristic 10), and the technical affordances of mobile devices align well with this heuristic (Heuristic 11.1). Please refer to heuristic 17.1 for the best ways to integrate words and visual elements to reduce cognitive load. Also, please refer to heuristic 16.1 from the learning styles section, to see how visual elements support multi-modal approaches. Overall, this heuristic supports multi-modal approaches by discussing the integration of words (aural and textual) with visual elements. However, if the VARK modalities are implemented individually without due care for multimodal approaches, then they may negatively impact heuristic 17.2.</p> <p>Please refer to heuristic 21.1 for a better understanding of the use of graphics in providing consistent navigational elements and signposts for learning. The overall objective of this heuristic is to reduce cognitive load; therefore it is closely related to other heuristics with this objective (Heuristics 17.1, 17.2, 18, 19, 21, 21.1).</p>
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ID	Heuristic Title:		
17.1	Apply contiguity by aligning words (audio or screen text) with corresponding graphics.		
<b>Learning Theory:</b>	Cognitive Theory	Load	<b>Pedagogical Area:</b> Reducing cognitive load
<b>Description:</b>			
It is important to avoid learning material that requires learners to split their attention between, and mentally integrate, multiple sources of information. The process of integrating distinct sources of information creates an unnecessary cognitive load that can be avoided by aligning and integrating words (audio or screen text) in close proximity (i.e. contiguous) to corresponding graphics.			
<b>Design and Evaluation Criteria:</b>			
To successfully apply contiguity of words and corresponding graphics the following guidelines should be considered in the development of the e-learning software and collaborative activities:			

- 1. For contiguity to apply, the multiple sources of information are essential for understanding, and difficult to understand in isolation.** Careful consideration must be given to the logical relation between the information: whether the information is complex, whether understanding is possible without integration, whether integration is negated by the learner's experience level, and whether the same information is being presented redundantly.
- 2. Place printed words near corresponding graphics.** Text should not be placed above or below the corresponding graphic, but as close as possible (even in) to the graphic. When parts of an object are being described, place the text close by and where necessary use a pointed-line to connect. When a process is being described, number and place the text close by, and where necessary use a pointed-line to connect. Please refer to Appendix B.8 for a brief outline of common mistakes in this area.
- 3. Avoid the overuse of text.** Long passages and too much text can become discouraging for many learners. This should be avoided by using multiple editing iterations to cut down the text to the bare essence. Please refer to Appendix B.9 for some tips on how to reduce unnecessary text.
- 4. Synchronise spoken words with corresponding graphics.** A spoken word narration that describes an animation or video should play at the same time and be synchronised with the corresponding animation or video. Providing separate controls for the audio and video or providing the audio and video in succession should be avoided.

#### **Educational Benefits:**

When words and graphics are separated from one another on the screen, or by different screens, or when narration and animation/video are separated in time, then the learner must use their scarce cognitive resources to match them.

1. Integrating text and graphics reduces extraneous cognitive load by removing the need for the learner to search for which parts of a graphic correspond to which words.
2. This, in turn, allows the learner to focus their cognitive resources on understanding the learning material.
3. By integrating them in this manner, they can be held together in working memory, therefore making a meaningful connection between them. This connection between words and graphics is an important part of the sense-making process that leads to deeper learning.

#### **Potential Challenges:**

Guideline-3 raises the critical issue of overusing text and thereby demotivating students; Appendix B.9 provides a number of strategies to alleviate this problem.

Another challenge is when the student is expected to focus on written text and graphics **simultaneously**, this challenge is mitigated in heuristic 17.2.

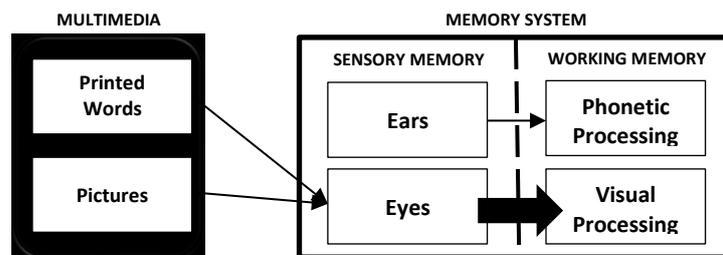
<b>Related Heuristics:</b>	Please refer to the Related Heuristics section in heuristic 17. In addition, guideline-3 provides criteria to not overuse text which has direct impact to heuristic 16.3.
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ID	Heuristic Title:
17.2	Representing words as audio, on-screen text or both

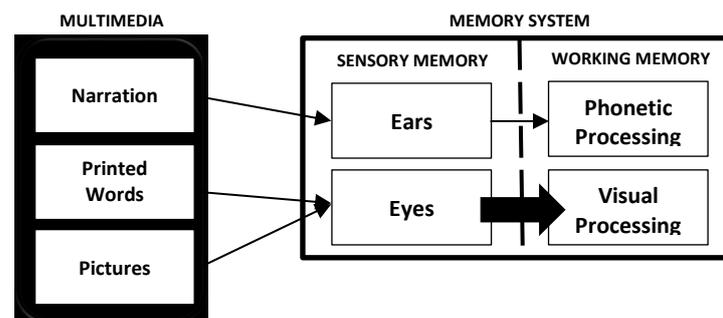
<b>Learning Theory:</b>	Cognitive Load Theory	<b>Pedagogical Area:</b>	Reducing cognitive load
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**Description:**

When words are accompanying visual elements, and both require the learner’s simultaneous attention, it is typically better to present the words as audio instead of on-screen text. This avoids cognitive overload by balancing the learning material across two separate cognitive channels - words in the auditory channel and graphics in the visual channel (Refer to [Figure 65](#)). Furthermore, it is typically recommended to not duplicate words via audio and screen text. This avoids situations where the learner focuses too much on screen-text to the detriment of the graphics or potentially focusing on the screen-text and narration and comparing whether they are equivalent (Refer to [Figure 66](#)). However, exceptions to these guidelines do apply.



**Figure 65: Overloading of visual channel with presentation of screen text and graphics.**  
Adapted from Mayer 2001.



**Figure 66: Overloading of visual channel with graphics explained by words in audio and screen text.**

### Design and Evaluation Criteria:

This heuristic promotes an increased focus on applying audio narration with visual elements, but also requires more discerning decision making in identifying when on-screen text remains the best learning option. Please refer to the following guidelines.

1. **Words communicated in audio form should be preferred over on-screen text if the text needs to be synchronised with more dynamic visual elements such as animations, videos, or series of static frames.**
2. **When explaining graphical elements, it is better to avoid duplicating words in both audio and screen text.**
3. **The audio material must be clear and concise, and synchronised with the visual learning material.**
4. **When you do not have simultaneous graphical presentation, then modality does not apply, and screen text alone can be presented.**

#### Exception Scenarios

5. **In some scenarios, keywords should still be highlighted on screen with visual elements to act as a graphical organiser and to direct the learner's attention.**
6. **With specific learning contexts and learning material, screen text should be preferred even if there is simultaneous graphical presentation.** For instance:
  - a. when words should remain available to the learner over time,
  - b. when the words are technical, unfamiliar or formulae,
  - c. when the words are not in the learner's native language,
  - d. when lengthy text is being presented or is necessary for future reference, or
  - e. when the text lists key steps in a procedure or gives directions in a practice exercise.
7. **There remain some conditions when the use of redundant on-screen text in conjunction with audio narration can give learning benefits:**
  - a. When there is no graphical element, you may decide to have narration and some text, therefore using [dual channels](#) and not overloading either.
  - b. The scenarios listed in guideline-6.
  - c. When there is ample time to process the visual elements; for instance, when text and graphics are presented sequentially or when the pace of the presentation is sufficiently slow.

<b>Educational Benefits:</b>	
<p>This heuristic balances the learning material across two separate cognitive channels thereby reducing the possibility that the visual channel becomes overloaded.</p> <p>Furthermore, it leads to deeper learning and is particularly beneficial for complex learning material.</p>	
<b>Potential Challenges:</b>	
<p>As outlined in the guidelines, this heuristic requires discerning decision making in identifying when audio narration or on-screen text is the best learning option.</p> <p>Additionally, audio material involves some additional challenges:</p> <ol style="list-style-type: none"> <li>1. It can introduce too much noise into the learning environment.</li> <li>2. It can add too much cost and potential delay.</li> <li>3. It cannot be changed or edited as quickly and easily as text if learning material changes.</li> </ol>	
<b>Related Heuristics:</b>	Please refer to the Related Heuristics section in heuristic 17. In addition, the guidelines in this heuristic provide additional criteria which affect the implementation of multi-modal learning thereby reducing cognitive load (Heuristics 16, 16.1, 16.2, 16.3, 16.4).

<b>ID</b>	<b>Heuristic Title:</b>		
18	Avoid adding learning content that does not directly support your instructional goal.		
<b>Learning Theory:</b>	Cognitive Load Theory	<b>Pedagogical Area:</b>	Reducing cognitive load
<b>Description:</b>			
<p>Learning content should directly support the instructional goals. There is a strong temptation to add extra material in e-learning that will grab the attention of students and keep them interested and engaged. This can lead to interesting but unnecessary learning material, the use of overly dramatic stories and examples, and gratuitous use of text, audio, visual and multimedia elements, which in turn can actually harm the learning process. It is important to note this is one of the most commonly violated principles but is relatively easy to implement and can give a significant learning improvement.</p>			
<b>Design and Evaluation Criteria:</b>			
<p>This heuristic promotes an increased focus on providing learning material that is concise and focused on the intended learning objectives. Refer to the following guidelines:</p> <ol style="list-style-type: none"> <li>1. <b>The learning material should not be embellished with unnecessary detail, or with graphics, audio, text or multimedia that focus only on creating interest.</b></li> </ol>			

2. **The interest and engagement should come from the core learning content and instructional design.**
3. **Avoid the addition of environment sounds and / or background music** since it can lead to a reduction in learning retention and transfer.
4. **Avoid pictures and graphics that are purely decorative** since they will not lead to improved learning.
5. **Avoid visual elements that are somewhat (indirectly or tentatively) related to learning objectives since they disrupt the learning process.**
6. **Use simpler visuals.** Simple visuals include visuals with fewer details presented at one time, such as 2-dimensional line drawings instead of 3D drawings or photos, or a series of static drawings instead of an animation or video.
7. **Avoid adding extraneous text with embellished textual or narrative descriptions,** in preference for concise, focused text or narrative.
8. **Avoid lengthy audio or video segments which can cause learner frustration from having to progress through the entire segment to extract the relevant learning.**

#### **Educational Benefits:**

The avoidance of unnecessary, embellished, overly detailed or decorative learning content enables a more accurate focus on instructional goals and improves learning performance. For example:

- Visual elements that are purely decorative do not lead to improved learning.
- Simpler visuals can lead to improved learning and retention since the learner is better able to focus on important visual elements and is not overwhelmed with too much detail.
- Visual elements that are somewhat (indirectly or tentatively) related to learning objectives can be harmful since they interfere with the learner's attempt to make sense of the material and disrupt the learning process.
- Environment sounds and / or background music can at best lead to no noticeable difference in learning, but at worst lead to a reduction in learning retention and transfer.
- Embellishing text or narration to add interest, expand upon key ideas or add greater technical depth all lead to reduced learning of target material.

#### **Potential Challenges:**

Due concern should be taken in the instructional design to balance constructivist principles and the need to gain the learner's attention, against the possibility of causing cognitive overload.

<b>Related Heuristics:</b>	<p>The overall objective of this heuristic is to reduce cognitive load; therefore it is positively related to other heuristics with this objective (Heuristics 17.1, 17.2, 18, 19, 21, 21.1). This heuristic should have a balanced considered in relation to a number of heuristics with constructivist and connectivist foundations (Heuristics 1, 1.1, 3, 4, 5, 6.2, 7, 12, 13). Appropriate learning material should be presented that is focused, concise and unembellished but still provides the richness that allows students to actively construct knowledge. Additionally, this heuristic must be carefully considered in relation to a number of motivation and multi-modal based heuristics (Heuristics 14, 14.1, 14.2, 14.4, 15, 15.1, 16, 16.1, 16.2, 16.3, 16.4). As discussed in heuristics 9 and 11, collaborative learning used for scaffolding purposes can also help reduce cognitive load, but in general, the overhead associated with social and collaborative learning must be considered since it can increase cognitive load.</p>
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ID	Heuristic Title:		
19	Optimise essential processing by segmenting learning material and providing pre-training.		
<b>Learning Theory:</b>	Cognitive Load Theory	<b>Pedagogical Area:</b>	Reducing cognitive load
Description:			
<p>In cognitive load theory, essential processing reflects the learning processes used by the student to understand the core learning material. It is fundamental to the learning process but is significantly impacted by the inherent complexity of the material. Therefore, to get better learning results, it is vital that the complexity of the learning material is effectively managed. Two approaches are suggested to manage this complexity: segmenting breaks a lesson into manageable segments that do not overload the student’s cognitive processes, and pre-training provides foundation information that gives names and characteristics of key concepts that can be built upon and used in the main learning segments.</p>			
Design and Evaluation Criteria:			
<p>To successfully implement pre-training and segmenting approaches the following criteria should be considered in the instructional design and implementation of the e-learning software and associated CLE activities:</p>			

- 1. Break learning material into smaller segments and present them sequentially.** Segmenting helps the learner manage complexity by breaking the lesson into smaller pieces that convey just two or three steps in the process or describe just two or three major relations between elements. These segments are then presented sequentially, under the learner's progress control, which in turn allows the learner to digest the material at their own pace.
- 2. Organise segments into metaphorical chapters.** To help transition students to new e-learning concepts, it can be helpful to mimic approaches they know and feel comfortable with. The e-learning software can be structured as chapters, complete with learning outcomes, learning material, an end of chapter summary and end of chapter review questions.
- 3. Provide a stable foundation for learning by giving a pre-training which orients the learner and explains terminology and pre-requisite concepts.** Even when learning material is segmented, it can sometimes still be complex or introduce a lot of unfamiliar terms or concepts. The pre-training principle reduces this complexity by giving the learner an orientation which explains the terminology or pre-requisite concepts. In effect, this redistributes some of the student's essential processing from the main lesson to the pre-training and provides a stable foundation for the student to build their learning on.

#### **Educational Benefits:**

The implementation of this heuristic leads to the following education benefits:

1. That breaking exactly the same educational material into manageable segments in comparison to a continuous presentation, results in improved learning as measured in learning transfer tests.
2. That students who receive pre-training outperform students on learning transfer tests and that such pre-training is most effective with students who are beginners to the subject area.
3. Using chapters gives structure to the learning experience, and using the chapter summary and review questions, reassert to learners the important learning material necessary for the examinable curriculum.

#### **Potential Challenges:**

To some extent, structuring learning material into chapters goes against constructivist and connectivist principles and the guided discovery inherent in problem-based learning. However, this pedagogy proposes a balance between extremes and seemingly incompatible

approaches. Moderate approaches should be used that can marry aspects of constructivism and problem-based learning within a more structured e-learning environment.

<b>Related Heuristics:</b>	<p>The overall objective of this heuristic is to reduce cognitive load; therefore it is positively related to other heuristics with this objective (Heuristics 17.1, 17.2, 18, 19, 21, 21.1).</p> <p>As mentioned previously to some extent structuring learning material into sections and chapters counteracts constructivist and connectivist principles and the guided discovery inherent in problem-based learning (Heuristics 1, 1.1, 4, 5, 6.2, 12, 13, 15.1). This heuristic can also run counter to the attention and satisfaction approaches proposed in the ARCS model (Heuristics 14, 14.1 and 14.4).</p> <p>However, the use of pre-training and segmenting aligns with social constructivist principles of scaffolding in which a student is supported to allow them to proceed to learning that is just beyond their current ability (Heuristics 4.1, 6.1, 8, 10). Furthermore, as discussed in heuristics 9 and 11, whilst collaborative learning, used for scaffolding, can help reduce cognitive load, the overhead associated with social and collaborative learning can also increase cognitive load.</p>
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ID	Heuristic Title:		
20	Use a conversational style in screen text and audio narration.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	Social Learning Authentic Learning
Description:			
It is recommended that the e-learning software should use a conversational style (using first- and second-person and active language) in both screen text and audio narration and should avoid the use of formal and passive voice. This helps the learner engage with the e-learning software in a manner closer to a social conversational partner.			
Design and Evaluation Criteria:			
The copywriting of the screen text and audio narration in the e-learning software and CLE activities should consider the following guidelines:			
<ol style="list-style-type: none"> <li><b>1. Use a more informal conversational style in narration and screen text to give learners a sense that they are in a conversation with a partner; this motivates learners to work harder to understand the material.</b></li> <li><b>2. The conversational tone and style mean using words like “I”, “we” and “you”.</b></li> </ol>			

3. Words and phrasing should be less formal but without reducing the importance of the learning material.
4. Do not overuse the conversational style to the point it becomes a distraction to learning; it should remain polite, friendly and respectful whilst not degenerating into slang and /or colloquialisms.
5. In an audio narration, make sure the voice of the narration is human with a standard accent instead of a computer-generated voice.

#### Educational Benefits:

In traditional teaching approaches, the teacher's primary role is to present information and the learner's role is to take on board that information. In contrast, cognitive theories of learning consider that learners work harder to understand the material when they feel they are in a conversation with a partner rather than receiving information. The conversational style therefore works on two levels; it presents the information but also primes the appropriate cognitive processes to motivate the learner to try to make sense of the learning material. Therefore, adjusting the text and narration to be more conversational, should lead to improved learning performance.

#### Potential Challenges:

NA.

#### Related Heuristics:

Using a conversational style offers broad moderate support to a large number of heuristics in this pedagogy. However, it offers direct support in motivating learners to attain their ZPD and in social dialogue, in gamification, and in aural and read-write modal preferences (Heuristics 9, 10, 15, 15.1, 15.2, 16.2, 16.3).

ID	Heuristic Title:		
21	Provide restricted navigational control in the e-learning software.		
<b>Learning Theory:</b>	Cognitive Load Theory	<b>Pedagogical Area:</b>	Reduce Cognitive Load.
<b>Description:</b>			
Learner control is implemented by navigational features that allow the learner to choose the path they take through the e-learning software, by selecting the topics and instructional elements they prefer, and the pace at which they undertake learning. This pedagogy recommends a restricted level of navigational control and focuses more towards program control. However, the learner must be given freedom in a number of key areas; these are the			

pace of learning, the ability to revisit content that has already been covered and to allow learners as much personal control (as possible) over their actual learning experience.

#### Design and Evaluation Criteria:

The successful implementation of this heuristic requires consideration of the following guidelines. The e-learning software should:

- 1. Restrict learners' ability to control the order of lessons, topics and screens within the e-learning software, but allow the previously covered material to be revisited.**
- 2. Display all important educational material as default in order to avoid it being skipped by the learner.**
- 3. Allow the learners' the flexibility to learn at their own pace.**
- 4. Balance a stable e-learning environment with learners need to feel in control and responsible for their success.** This guideline is duplicated from heuristic 14.3 guideline-3, since it is critical that it is considered within this heuristic.
  - a. Guidelines 1 to 3 and heuristic 21.1 provide a stable learning environment that sets the standards expected and guides the learning experience.
  - b. Within that stable learning environment, allow the learners as much personal control (as possible) over their actual learning experience. Techniques that support such personal control are:
    - i. Foster an environment where it is ok to make mistakes and learn from them.
    - ii. Use learning activities and problem-based methods that require the learner to exercise personal control and judgement to solve.
    - iii. Provide corrective feedback that helps the learner see the cause of their mistake and allows them to learn and retry.

#### Educational Benefits:

The tacit expectation is that more learner control will improve learning and will satisfy the learner's desire for more control. However, the challenge is that often learners may not have enough self-awareness and meta-cognitive skills to accurately judge what they already know, what they need to learn and in selecting instructional elements with learning value.

The benefits from focusing the e-learning software towards program control rather than learner control are that:

- It reduces the extraneous cognitive load of the learner having to understand their own learning needs accurately and plan their path through the e-learning software,
- With learner control, low prior knowledge learners may choose to view up to 50% less learning screens.

- Low prior knowledge learners typically perform worse under learner control; whilst high prior knowledge learners typically perform equally well under both scenarios.

**Potential Challenges:**

An important challenge within this heuristic is to restrict the learner’s navigational control and ensure they cover as a minimum the necessary educational material, but without eroding the learner’s feelings of personal control and responsibility for their own learning.

**Related Heuristics:**

The overall objective of this heuristic is to reduce cognitive load; therefore it is positively related to other heuristics with this objective (Heuristics 17.1, 17.2, 18, 19, 21, 21.1). To some extent, this heuristic goes against constructivist and connectivist principles (Heuristics 4, 6, 6.2, 12 13,) espousing complete freedom of the student to construct their own knowledge individually. This heuristic can also run counter to the attention and satisfaction approaches proposed in the ARCS model (Heuristics 14, 14.1 and 14.4). The objective of this heuristic is not to force one educational view on the students, but to ensure that all students at least have the opportunity to study the requisite learning material whilst constructing their knowledge. Furthermore, the structure this heuristic brings to the e-learning software can help learners gain confidence and ultimately for them to reach their ZPD (Heuristics 10, 14.3). In addition, the technical affordances / potential constraints of mobile devices (Heuristic 11.1) align with the objective of providing structure through restricted navigational control.

ID	Heuristic Title:		
21.1	Provide consistent navigational elements and signposts for learning.		
<b>Learning Theory:</b>	None	<b>Pedagogical Area:</b>	E-learning best practice.
Description:			
The e-learning software should provide a clear and consistent Graphical User Interface (GUI) that places a minimal cognitive demand on the learner and intuitively supports learning. One important part of this is to provide clear navigational elements and visual cues (signposts) of the learning material that emphasises recognition rather than recall.			
Design and Evaluation Criteria:			
The successful implementation of this heuristic requires consideration of the following guidelines. The e-learning software should:			

1. **Provide a clear, consistent and meaningful navigational interface** (navigational menus, movement buttons, course maps, multimedia controls, etc.) that allows the learner to intuitively progress through the e-learning software and control the educational material.
2. **Provide clear, consistent and meaningful signposts for learning**, such as a course map, learning objectives, screen titles, embedded topic headers, labels, summaries, links (including summary previews), etc.
3. **Ensure pre-training and/or a guide is provided to learners** that explains the navigational interface and learning signposts.

**Educational Benefits:**

Mechanisms used to signpost instructional elements and learning content signal their importance to learners and improve retention and comprehension.

**Potential Challenges:**

NA

**Related Heuristics:**

Please refer to the Related Heuristics section in heuristic 21.

## 10 GLOSSARY

Glossary Term	Description
<b>Accommodation</b>	In relation to constructivist principles, accommodation is the process by which existing schemas have to be altered to cope with new experiences that contradict the existing mental model.
<b>Active Processing</b>	According to Cognitive Load Theory, human learning occurs when the appropriate cognitive processes are engaged to mentally organise incoming auditory and visual sensory information and integrate it with existing knowledge so that it can be stored in and recalled from long-term memory.
<b>Assimilation</b>	In relation to constructivist principles, assimilation is the process by which new information reinforces an existing schema, and the schema is augmented with new information
<b>Behaviourism</b>	Behaviourism is a systematic approach to the understanding of human or animal behaviour; it assumes that behaviour is a consequence of individual history. Behaviourism gives particular focus to positive reinforcement and punishment, together with the individual's current motivational state and controlling stimuli.
<b>Collaboration</b>	Collaboration involves a joint group endeavour to solve the problem; all group members contributing to the same task.
<b>Collaborative Learning Environment (CLE)</b>	A collaborative learning environment is a software system that offers various tools and services that support learners in working and learning together.
<b>Cognitive Load Theory (CLT)</b>	CLT explains how incoming information from the eyes and ears is transformed into knowledge and skills in human memory. It proposes that learners do not passively receive incoming information, but instead undertake active cognitive processes that organise the incoming information into logical structures and integrate it with existing knowledge for long-term recall.
<b>Constructivism</b>	Constructivist approaches recognise a real world that sets limits on our experiences, but proposes that there is no uniformly perceived single reality; in fact, each person's perception of

	reality is a mental construct founded on interpretation of their interactions with the world. An individual's reality is therefore based on their existing experience and understanding, which is in turn used to make sense of their current perception of events.
<b>Cooperation</b>	Cooperation involves the division and assignment of tasks within the group to solve the problem.
<b>Deep Learning</b>	As opposed to surface learning, in which learning material is passively memorised with a primary aim of passing assessments; deep learning is learning where there is a vigorous interaction with the learning material to truly understand it and integrate it with previous experience and knowledge. Meaning it is integrated into existing mental schemas in the learner's long-term memory.
<b>Dual Channels</b>	Humans have separate channels for processing visual and auditory material.
<b>Equilibrium</b>	In relation to constructivist principles, equilibrium is the process of arriving at a stable state where there is no longer conflict between new knowledge and existing mental schemas.
<b>Extrinsic</b>	Not forming part of or belonging to a thing, or originating from the outside. Typically, something originating outside of a thing and acting upon that thing.
<b>Far Transfer</b>	Far Transfer is the application of skills and knowledge learned in one situation to a different situation. It builds upon deep learning and requires learners to adjust the underlying principles they have learnt, for use in a new scenario or new problem.
<b>Gamification</b>	Gamification is the use of game design elements in non-game contexts. It does not focus on creating fully fledged games, but instead uses game dynamics, mechanics, and frameworks to increase pleasure, fun, motivation and influence behaviour.
<b>Generation Y</b>	Generation Y refers to the specific generation born between the 1980's and 2000; this term was given to this generation since they succeed Generation X. They are defined by a number of characteristics, one of the most notable being that they were

	born and raised in an emerging world of technology, arguably making them inherently knowledgeable of digital technologies.
<b>Heuristic</b>	A heuristic is a specific rule-of-thumb or argument derived from experience
<b>Higher Order Thinking</b>	Higher Order Thinking theorises that some types of learning are more valuable, but require more cognitive processing and are more difficult to teach and learn. According to Bloom's taxonomy analysis, evaluation and synthesis are thought to be of a higher order as compared to remembering, understanding and applying facts and concepts.
<b>Intrinsic</b>	Belonging to the essential nature or constitution of a thing or originating and included wholly within an organ or part.
<b>Mental Model</b>	Mental models are our internal symbolic representation of external reality. They explain our thought process about how something works in the real world and shape our behaviour and approaches to solving problems.
<b>Metacognition</b>	Metacognition is "cognition about cognition"; in this context, it relates to thinking about one's own thinking process such as study skills, memory capabilities, and the ability to monitor learning. It is self-awareness of our own cognitive processes and the understanding of how to regulate those processes to maximize learning.
<b>Mindful Activity</b>	Mindful Activity is activity in which the learner is in direct contact with real or virtual objects and is encouraged to manipulate them in order to think, hypothesise and test their hypothesis.
<b>Multi-Modal</b>	Multi-modal approaches combine a mixture of approaches and teaching methods to offer balanced modal coverage.
<b>Learning Theory</b>	Learning theories are conceptual frameworks that describe how humans acquire new, or modify or reinforce existing knowledge, behaviour, skills, values, or preferences.
<b>Limited Mental Capacity</b>	At any given time, humans can actively process only limited information in each channel; material that exceeds this threshold may enter working memory but will not be processed and encoded into long-term memory.

<b>Orienting Reflex</b>	Orienting Reflex is an organism's immediate response to a change in its environment, that change is not sudden enough to elicit the startle reflex, but is a novel or significant stimuli. This initial response makes the organism temporarily more sensitive to the stimulation.
<b>Part-task Instruction</b>	Traditional teaching methods take a part-task approach which breaks the syllabus down into small parts that teach topics and sub-topics; these are in turn followed by frequent (relatively small) practice activities. This approach gradually builds knowledge and skills in the learner.
<b>Pedagogy</b>	Pedagogy focuses on the theory and practice of education, more specifically the study and practice of how best to teach and assess.
<b>Problem Manipulation Environment</b>	As part of active learning, students are encouraged to engage in mindful activity in which they manipulate real or virtual objects to support their thinking and reflective processes, and to test their hypothesis. This environment should have a low floor in terms of ease of entry and a high ceiling in terms of features and functionality that learners can eventually master. In a computing context, such an environment should allow students to model and run simulations, look-under-the-hood on existing solutions, employ trial and error, implement designs, and test and debug solutions.
<b>Progressive Disclosure</b>	Progressive Disclosure is an instructional technique used to reduce cognitive load by disclosing the minimal learning material required and releasing more information progressively thereby avoiding learners being overwhelmed. This technique can also be used to create curiosity and maintain suspense by not providing all the necessary material in one go.
<b>Reflective Practice</b>	Reflective practice is the capacity to reflect (think deeply or carefully) on our actions or thought processes in order to develop insight that in turn enables improvement. It is argued that experience alone does not necessarily lead to learning; deliberate reflection on experience is essential.

<b>Schema</b>	Schemas are the mental constructs that organise and categorise our skills, and knowledge and understanding of the world.
<b>Sensation-seeking Reflex</b>	Sensation seeking is a personality trait with a biological basis defined by the <i>"seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience"</i> (Zuckerman 1994, p.27)



## **12 REFERENCES**

Removed for brevity and to reduce duplication. Please refer to thesis Reference section for a full set of references.

## **13 BIBLIOGRAPHY**

Removed for brevity and to reduce duplication. Please refer to thesis Reference section for a full set of references.

## **E E-LEARNING PEDAGOGY – APPENDICES DOCUMENT**

As discussed in section 4.2 of the thesis, the e-learning pedagogy was iteratively developed and refined through the three phases of this research study. Five versions of the e-learning pedagogy were developed and released. In the first two versions the appendices were included in the pedagogy document, and in the last three versions, the appendices were presented in a separate document. As a reference, this appendix contains the fifth and final version of the pedagogy appendices document: Computer Science E-Learning Pedagogy Appendices v0.5. In the interest of brevity and to avoid duplication, the lengthy bibliography section is not included in this version.

**Pedagogical heuristics for the design and  
evaluation of e-learning software for high school  
computing**

**Appendices Document**

**By  
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A document deliverable submitted in partial fulfilment of the requirements for the  
degree of Doctor of Philosophy at the University of Central Lancashire



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## DOCUMENT DETAILS

### Document Version

Pedagogy Ver	Date	Phase	Document Name
0.7	04/02/2015	Phase 1	Appendices included in the pedagogy document: GCSE Computer Science E-Learning Pedagogy v0.7
1.2	01/12/2015	Phase 2- Cycle1	Appendices included in the pedagogy document: GCSE Computer Science E-Learning Pedagogy v1.2
1.5	05/06/2016	Phase 2- Cycle2	Computer Science E-Learning Pedagogy Appendices v0.3
1.7	04/10/2016	Phase 3	Computer Science E-Learning Pedagogy Appendices v0.4
1.8	02/10/2018	Final	Computer Science E-Learning Pedagogy Appendices v0.5

### Document Distribution

Name	Role	Institution	Date

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### Note on Referencing

This document is based on a significant literature review of relevant educational research. Where specific points are clearly attributable to an author, they are referenced accordingly (refer to reference section). However, in the interest of readability, underlying theories and

concepts have not been referenced with academic rigour; this in no way implies that Peter Yiatrou is the source of these theories and concepts

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# A BRIEF PRIMER ON LEARNING THEORIES AND INPUTS TO THE PEDAGOGY

## A.1 Learning Theories

Learning theories are conceptual frameworks that describe how humans acquire new, or modify or reinforce existing knowledge, behaviour, skills, values, or preferences.

### A.1.1 Constructivism

Traditional objectivist approaches contend that there is one true and correct reality, which can be taught to a learner. In contrast, constructivist approaches recognise a real world that sets limits on our experiences, but proposes that there is no uniformly perceived single reality; in fact, each person's perception of reality is a mental construct founded on interpretation of their interactions with the world. An individual's reality is therefore based on their existing experience and understanding, which is in turn used to make sense of their current perception of events. The mental constructs that organise and categorise our skills, and knowledge and understanding of the world are called schema.

In this light, constructivists view learning as the result of active mental construction, where new information is built into an individual's current mental models (schema). Piaget (1969), one of the founding fathers of constructivism, proposes that external experience can reinforce existing mental models or contradict them, leading to the following:

- **Assimilation** – the process by which new information reinforces an existing schema, and the schema is augmented with new information.
- **Accommodation** – the process by which existing schemas must be altered to cope with new experiences that contradict the existing mental model.
- **Equilibrium** – the process of arriving at a stable state where there is no longer conflict between new and existing knowledge.

Constructivist principles are claimed to offer several learning benefits, including:

- Better and deeper understanding since it emphasises authentic and active learning;
- An increase in motivation since students feel more in control, and are closer to their perceived reality;
- An increase in social skills since constructivism focuses heavily on interacting, perceiving and interpreting the world, often through dialogue; and
- A focus on the big picture, promoting problem-solving and higher-order thinking.

However, there are also counter-arguments that counsel a measure of caution, and raise concern over the complexity of implementing a curriculum using constructivist approaches, and the challenge for teachers to transition from instructivist to constructivist approaches. There are warnings over the learner's ability to construct their own knowledge, and that the perceived lack of guided instruction in constructivist approaches can allow learners to create their own "*private universe*" to explain complex phenomena. This, in turn, calls into question the accountability that what students learn is aligned with expected learning outcomes. Additionally, there are significant concerns over the additional cognitive load expended by students within constructivist approaches. In a comparative analysis of objectivist and constructivist approaches, Vrasidas (2000) acknowledges that some learners may find constructivist approaches intimidating and complex, and in some learning contexts, didactic instruction may be more appropriate. Such concerns are to some extent valid if considering extreme constructivist positions, in which students have almost unlimited discretion to structure their own learning. It is for this reason that the proposed pedagogy takes a moderate constructivist strategy in which constructivist values are translated into more tangible instructional design principles, or in the case of this study, into specific e-learning heuristics.

It is important to note that in the US, the national teacher associations have endorsed constructivist lesson design and instructional practices, and that constructivist approaches underlie the US National Research Council's proposal that active learning is adopted in schools (Brooks & Brooks 1999; Crick 2017). Furthermore, a recent literature review commissioned by the Royal Society to summarise what is known about pedagogies for teaching computing in schools, recognises that: constructivist principles have had a wide-ranging impact on learning theories and teaching methods; have been an underlying theme of many education reform movements across the world; and have been proposed as a suitable pedagogy for computer science, and in particular for computer programming (Crick 2017). This advocacy of constructivist approaches is with the full recognition that there remains debate regarding the tension between constructivist exploration and the controlled progression of the teaching of more complex concepts (Waite 2017). It is with recognition of this tension and debate that the proposed pedagogy takes a moderate constructivist approach in which students should construct their own knowledge, but should also be given instructional guidance and support via the e-learning software and their teachers.

### **A.1.2 Social Constructivism**

As its name implies, social constructivism is closely related to constructivist principles; both theories are based on knowledge being actively constructed. However, constructivism focuses on knowledge construction “*in the head of the learner*” (intra-psychological), while social constructivism proposes that knowledge is created through social interaction (inter-psychological), often with a more knowledgeable other. Although each theory has its own perspective on exactly when and where knowledge is constructed, they are complementary. An individual’s current knowledge forms the basis of their contribution to the dialogue. Then through this dialogue, new shared knowledge is constructed and is then assimilated by the individual learners, which in turn feeds into the next cycle of social interaction.

Vygotsky (1978; 1986), one of the earliest proponents of social constructivism, suggested two key components in learning: “*language*” and “*scaffolding*”. According to Kop and Hill (2008) Vygotsky postulated that self-talk (language) allowed children to work through complex problems by externalizing them as a form of self-guidance and self-direction. This in turn forms the basis of learners’ externalising problems through language and social interaction. Language becomes the form for communicating ones existing knowledge and entering into dialogue with others to solve a problem.

The second critical component within social constructivism and Vygotsky’s work, is scaffolding; the process by which supportive interactions between the learner and a more knowledgeable other enable the student to achieve something beyond his or her existing capabilities. The aforementioned knowledge or activity that is just beyond the learner’s current independent efforts is in the learner’s Zone of Proximal Development (ZPD) (Vygotsky 1978).

Working at the ZPD stretches the learner’s existing capabilities and encourages them to the next higher level of learning, which is postulated by Vygotsky (1978) to improve students developmentally <sup>7</sup>. The focus on social interaction promotes higher order thinking by encouraging learners to develop, evaluate, and appreciate multiple perspectives on an issue.

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<sup>7</sup> Vygotsky postulates a link and interchange between a student’s learning and their development (physical/mental maturation).

### **A.1.3 Collaborative Learning**

Closely aligned with Social Constructivism is Collaborative Learning. There is a significant body of research that discusses and broadly supports collaborative learning; this in turn has been extended into the realm of technology-assisted collaborative learning. Furthermore, it is argued that technology-assisted collaborative learning is all the more pertinent in the current knowledge society, in which people engage in teamwork that is information- and technology-rich. Finally, it is postulated that this trend will likely continue for the foreseeable future.

Historically, it has been argued that the focus of traditional schooling on individual student abilities and knowledge actually inhibits effective learning by creating barriers to social learning, but in recent years there has been an increased willingness to consider collaborative learning in a school context. In particular, collaborative learning has garnered research support in computer science education.

It is proposed that learning most naturally occurs not in isolation, but by students working together. Discussion allows them to share information, summarise points, verify and test their knowledge, and debate their opinions. It helps the student understand the views which they disagree with, and consider multiple perspectives when solving problems. Also, by focusing groups of students on the common objective of solving a problem, it gives them a common impetus to stimulate their learning and through the discussion, debate, contradiction and construction necessary in solving the problem, it arguably helps them reach their full potential. In the computer science field, the terms "*cooperation*" and "*collaboration*" are often used to indicate a subtle difference; cooperation involves students' dividing and assigning tasks within the group to solve the problem, whereas collaboration involves a joint group endeavour to solve the problem (Dillenbourg et al. 1995). This pedagogy uses the term collaborative to cover both cooperative and collaborative learning; however, it should be noted that the typical focus is on collaborative learning (as defined previously).

Moore (1989), Hillman, et al (1994) and more recently Dron (2007) proposed a number of interaction types for distance and collaborative learning. In consideration of their work, this pedagogy focuses on the following interaction types: student-teacher, student-student, student-content, group-group, learner-group, and teacher-group. The overriding objective is that the Collaborative Learning Environment (CLE) software will give learners access to shared information and the tools for learners to work collaboratively and to construct shared knowledge.

According to Slavin: *“there is a fair consensus among researchers about the positive effects of cooperative learning on student achievement”* (2011, p.345). However, not all research findings place the same value on collaborative/cooperative learning, the best circumstances to use it, and the most effective collaborative practices. Although, when used with appropriate preparation and support, and with a clear instructional goal, it can lead to educational benefits, such as: improved student achievement; improved long-term retention and higher-order thinking; and increased student motivation. Furthermore, where task/learning complexity is high, dividing the processing of information across students gives further benefit since it allows information to be distributed across a larger reservoir of cognitive capacity. But the inverse must also be considered, where the cognitive load exerted by the task/learning is low, the recombination and coordination inherent in collaborative learning cause an unnecessary overhead.

#### **A.1.4 Connectivism**

One of the most influential proponents of Connectivism, George Siemens (2004; 2006; 2008), proposes that Connectivism is a learning theory for the digital age, and positions it as a successor to existing theories. Connectivists contend that existing learning theories are no longer adequate in the face of our improved understanding of learning, the increasing pace of knowledge growth, the ubiquity of technology, the unmet expectations of recent generations (Generation Y, Millennials, etc.), and the great complexification of knowledge.

Connectivism posits that learning can occur outside of people and that in fact learning is the network; citing Siemens and Downes forum responses, Kop and Hill (2008) summarise that the creation of connections between information nodes signifies knowledge, and that the ability to recognize patterns within complex networks, and to traverse these information nodes, comprises learning.

Despite Siemens’ protestation that Constructivism and Social-Constructivism do not consider learning outside of people and that they are outdated, he sees a small measure of alignment with Constructivism in that constructivist *“Classrooms which emulate the “fuzziness” of this learning will be more effective in preparing learners for life-long learning”* (Siemens 2004, p.2). In addition, the closer link between Connectivism and Social-Constructivism is well-documented. Connectivism seems to intuitively reflect the realities of our digitally saturated world and the necessity of lifelong learning (typically, outside of formal institutions), and as such has a number of practitioners that support and adopt connectivist approaches. Connectivists argue that the

focus of existing learning theories does not satisfactorily reflect learning in today's interconnected world, and that there is an educational paradigm shift away from students being taught by teachers, typically in a classroom context. This paradigm shift is rooted in the new opportunities and challenges brought about by the exponential growth and complexity of information available on the internet, new possibilities for people to communicate on global networks, and the ability to aggregate different information streams.

Balancing popular support, there is academic debate on whether connectivism has the rigour to be a true learning theory, whether it is supported by an empirical body of evidence, and whether it replaces more established theories. However, what is clear is that the contemplation of connectivism does add value in the development of new learning paradigms and in particular, in the development of this pedagogy.

In accordance with Siemens (2004) the main principles of Connectivism are as follows:

1. Learning and knowledge rests in diversity of opinions.
2. Learning is a process of connecting specialized nodes or information sources.
3. Learning may reside in non-human appliances.
4. Capacity to know more is more critical than what is currently known.
5. Nurturing and maintaining connections is needed to facilitate continual learning.
6. Ability to see connections between fields, ideas, and concepts is a core skill.
7. Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities.
8. Decision-making is itself a learning process (i.e. choosing what to learn and its meaning in the current context).

Extreme connectivist positions as related to Illich's (1971) educational vision of de-schooling and '*community webs*' are not considered in the e-learning pedagogy. Instead the above principles are considered as the basis of the moderate connectivist approach reflected in the heuristics.

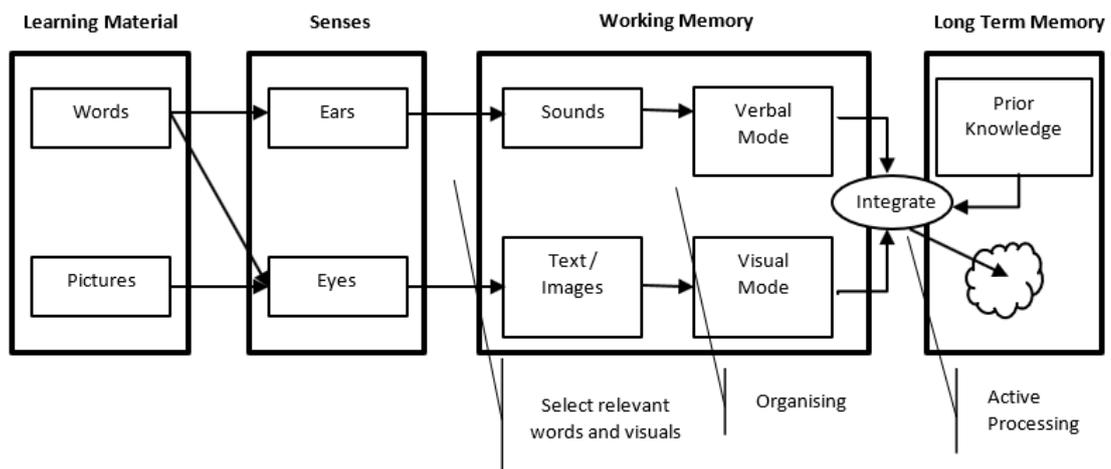
### **A.1.5 Cognitive Load Theory**

Cognitive Load Theory (CLT) considers the human cognitive architecture and processes, and their inherent limitations, in explaining how incoming information from eyes and ears are transformed into knowledge and skills in human memory (Sweller et al. 1998). There is well established support for the consideration of cognitive load in: instruction, computer science instruction, and e-learning; and a wide body of research on approaches to reduce and optimise cognitive load. As outlined by Clark and Mayer (2011) CLT proposes that learners do not

passively receive incoming information, but instead undertake active cognitive processes that take in relevant information, organise it into logical structures, and integrate it with existing knowledge for long term recall. CLT is based on three main principles:

1. **Dual Channels** - Humans have separate channels for processing visual and auditory material.
2. **Limited Mental Capacity** – At any given time humans can actively process only limited information in each channel; material that exceeds this threshold may enter working memory but will not be processed and encoded into long-term memory.
3. **Active processing** – Human learning occurs when the appropriate cognitive processes are engaged to mentally organise incoming auditory and visual sensory information and integrate it with existing knowledge so that it can be stored in and recalled from long-term memory.

The above principles and learning process are represented in [Figure 67](#).



[Figure 67: Cognitive theory of learning](#)

(Adapted Mayer 2005)

This model of learning leads to three types of cognitive processing.

1. **Essential (intrinsic) processing** is the processing of the core learning material, and is dependent on the inherent complexity of the material. The correct application of guidance, scaffolding and segmenting of learning material can support it.
2. **Extraneous processing** is processing that does not support the instructional objectives and is created by poor instructional design and the inclusion of irrelevant or duplicate learning material.
3. **Generative (Germane) processing** is processing aimed at the development of new schemas or integration into existing schemas, and the automation of these schemas. It

is aimed at deeper understanding (and far transfer) of the core material by motivating the learner to make sense of the material and integrate it into their schemas so that it can be recollected and applied in the appropriate circumstance.

Considering CLT, an appropriate instructional strategy is therefore to:

1. Support the learner in selecting the important information in the lesson (signposting).
2. Support the learner in managing the limited capacity of working memory by:
  - a. Minimising extraneous cognitive load by a careful focus on the core learning material.
  - b. Optimising essential processing by the careful management of the complexity of the core learning material.
3. Maximise generative cognitive processing by providing an opportunity for non-trivial practice activities, guided instruction, and authentic (relevant) examples and problems. This enables integration into existing schemas, and the hooks to allow for retrieval at a later stage.

CLT's positive impact on learning performance (retention) is well established; however, it is also contended that judicious use of cognitive load approaches improves germane processing, hence deep learning and far transfer.

In many respects constructivism and CLT, model the same learning processes, but from differing perspectives. Both focus on the active construction of knowledge and skills as schemas. But constructivism focuses on principles of authenticity and active learning and how new learning is assimilated or accommodated in schemas. Whereas, CLT takes an information processing perspective and focuses on the efficiency of the learning process and the different types of memory used during learning. In spite of their potential similarities, it is well recognised that there lies a tension between constructivist principles and CLT, in particular between discovery-based learning (problem-based learning) and CLT. This is addressed in the proposed pedagogy and the underlying formulation of heuristics, by focusing on moderate constructivist approaches, explanatory feedback and scaffolding, and guided discovery<sup>8</sup>.

In relation to collaborative learning, Kirschner et al. (2009, p.31) argue that "*learning by an individual becomes less effective and efficient than learning by a group of individuals as task complexity increases.*" Therefore, where learning material is intrinsically complex and

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<sup>8</sup> As oppose to pure discovery-based learning.

demanding, then collaborative learning may be appropriate since it *“allows information to be divided across a larger reservoir of cognitive capacity.”* The inherent complexity of the learning material must be carefully considered since for less complex learning the coordination, recombination and collaborative learning processes add an unnecessary cognitive overhead. Irrespective of this, the use of collaborative learning must always be structured, appropriately prepared, and guided to reduce extraneous cognitive processing.

In relation to multi-modal learning, CLT’s dual channel principle offers partial support for multi-modal learning via visual and aural channels; however, full multi-modal learning via all four VARK modalities is considered to create a high extraneous cognitive load.

In relation to learner motivation, Keller and Suzuki (2004) assert that motivational approaches, in particular related to the relevance dimension, can be aligned with CLT; however, it should be noted that unrestrained motivational approaches can negatively impact cognitive load.

Overall, a central theme within the pedagogy is that the use of pedagogical heuristics in all other areas must be considered in light of their potential impact on cognitive load.

A final consideration within CLT is the prior knowledge and expertise of the learner (i.e. existing schemas); several of the approaches within CLT support low-knowledge learners, but may not support or may even impede high-knowledge learners. This is called the expertise reversal effect. This considers that the level of CLT support must be tailored to the level of expertise of the learner and should typically be gradually faded.

## **A.2 Additional Theoretical Inputs to the Pedagogy**

### **A.2.1 Learning Motivation**

Learning requires significant mental effort; therefore, students need to be suitably motivated to devote the mental energy to learn. There is a significant body of research recognising that motivation is as an important factor and precursor to learning.

Motivation is a characteristic inherent within each learner, but must be fostered and enhanced by the learning material and instructional design of the lesson (Cook et al. 2009). Its impact on learning is complex and underpinned by a multifaceted interplay of factors such as: the students’ level of self-efficacy and self-regulation; situational and individual interest; extrinsic and intrinsic motivation; and performance and mastery goals, etc. Lepper et al. (2005) maintain that there is over a half a century of research into intrinsic motivation and its impact on learning, but assert

with concern that recent trends in schools show: *“The lower levels of intrinsic motivation for older versus younger children.”* (2005, p.193)

In contrast, e-Learning and technology-enhanced learning are often viewed as inherently motivational, arguably in many instances due to temporary novelty value; but in addition, they also offer motivational affordances that can help make learning more engaging. However, it is crucial that these motivational affordances be considered deeply within the instructional design of the e-learning, otherwise it still runs the danger of being a novelty to learners that quickly loses its appeal. Furthermore, there are counteractive motivational forces to be considered since despite the popularity and global growth of e-learning and online learning delivery, there remains historic challenges in stimulating and maintaining learner motivation in e-learning, and in particular in distance learning; this is most evident in the high drop-out rates in independent distance learning. This has led to a significant volume of research into the importance of learner motivation in e-learning, as well as the technological affordances and pedagogical theory that support it.

In particular, this pedagogy focuses on John Keller’s ARCS model (1987a; 1987b; 2008; 2006). For many years, Keller has been developing and testing a systematic process for analysing learner motivation and designing motivational techniques focused on the following areas: Attention, Relevance, Confidence and Satisfaction (ARCS). Keller (1987a), defines the ARCS categories as:

1. **Attention:** Capturing the interest of learners; stimulating the curiosity to learn,
2. **Relevance:** Meeting the personal needs/goals of the learner to affect a positive attitude,
3. **Confidence:** Helping the learners believe / feel that they will succeed and control their success, and
4. **Satisfaction:** Reinforcing accomplishment with rewards (internal and external).

The ARCS model is based on a comprehensive review and synthesis of motivational research; its conceptual validity has been confirmed in numerous research and it has been successfully applied and validated in e-learning instruction.

### **A.2.2 Gamification**

According to Deterding et al., gamification is *“the use of game design elements in non-game contexts”* (2011, p.9); in this case, the context is education. Gamification does not focus on creating fully fledged games, but instead uses game dynamics, mechanics, and frameworks to

increase pleasure, fun, motivation, and to influence behaviour. In the context of this research, it is to increase student motivation and ultimately to increase learning performance.

Gamification has been a trending topic in recent years with significant commercial interest and usage, and a significant growth in academic papers. Despite the growing number of papers published on gamification, there remains a lack of clarity on what the gaming affordances proposed in gamification are and how to effectively design a gameful system. Hamari et al. (2014) suggest that the most common gaming affordances are points, leader-boards, achievements/badges, levels, stories, clear goals, feedback, rewards, progress and challenge. These are taken as the basis of the gamification heuristics proposed in this research. Additionally, Hamari et al. and various other studies, suggest that the empirical evidence for gamification is mixed, although overall is positive.

Gamification has significant potential, but unfortunately, suffers from a tarnished reputation; all too often, the complexity of well-designed games are merely reduced to their more superficial elements. Deterding (2012) argues that the current stock implementation of gamification focuses on the least important parts of games, such as points, badges and leader-boards, and adds them to mundane user activities. As quoted by Deterding, Elizabeth Lawley, a professor of interactive games and media, counsels that when a comprehensive set of gaming affordances are considered and appropriately implemented, "*gamification can help enrich educational experiences in a way that students will recognize and respond to*" (2012, p.17). Based on their analysis, Stott and Neustaedter go one step further and advise that "*the underlying dynamics that make games engaging are largely already recognized and utilized in modern pedagogical practices, although under different designations*" (2013, p.1). This point is recognised in this research, ensuring the integration of a comprehensive set of game affordances into the proposed pedagogical heuristics.

### **A.2.3 Computational Thinking**

Jeannette Wing, one of the key proponents of Computational Thinking (CT), defined computational thinking as involving "*solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science*" (2006, p.33). In 2011, she further clarified that computational thinking is "*the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent.*" (Cuny, Snyder, Wing, 2010, cited in, Wing 2011, p.60). It is important to note that the term information-processing agent does

not necessarily mean a computer system; computational thinking does not inherently lead to computer solutions. It is more focused on reformulating seemingly difficult real-world problems that are complex, messy and partially defined into a form that is manageable and can be solved. It does this by borrowing concepts and mental tools from computer science such as abstraction, generalisation, iteration, recursion, decompositions, modelling, automation and algorithms. The aim is not to get humans to think like computers, but to marry the rigour and transparency of computing techniques with the ingenuity, imagination and creativity of humans. In recent years, computational thinking has gained momentum and received significant publicity.

Wing argues that computational thinking will be a fundamental skill used by everybody by the middle of the 21<sup>st</sup> Century, and that it should be added to every child's analytical ability in the same way as reading, writing and arithmetic. This opinion is being taken seriously and computational thinking is being integrated into the national curriculum of several nations. For example, in the UK (Brown et al. 2014):

*"A high-quality computing education equips pupils to use computational thinking and creativity to understand and change the world"* (DfE 2013, p.151).

In the United States:

*"the approach to problem-solving generally described as CT is a recognizable and crucial omission from the expertise that children are expected to develop through routine K–12 Science and Math education (although CT has finally been mentioned, albeit briefly, in the 2012 NRC K–12 Science Education framework)"* (Grover & Pea 2013, p.4).

It is argued that use of computers and computational thinking have revolutionised research and innovation in science, engineering and other disciplines. The Royal Society gives a number of examples of where computational thinking is radically influencing other disciplines: the Human Genome Project, the Large Hadron Collider, predicting global climate change, analysing the spread and control of infectious diseases, the Airbus fly-by-wire system, and the pharmaceutical sector (The Royal Society 2012).

However, there needs to be some caution since there remains a variety of academic and pedagogic interpretations of what computational thinking is, what differentiates it from other thinking skills, how best to teach it, and what can realistically be expected from our children. This lack of a consistent and coherent definition is causing some negative repercussions since the misleading message propagated by popular media and received by parents and teachers is that computational thinking equates with coding.

Another area of concern is that currently there is not a wealth of empirical evidence to link computational thinking to improved problem solving or far transfer to other problem domains. In addition, as noted by Hemmendinger (2010) perhaps computer scientists are to some extent guilty of arrogance and overreaching in that many of the elements claimed to be part of computational thinking have been around for a while, and are not within the sole domain of computer science. The pedagogical heuristics proposed in this research will not focus on these academic debates, but instead concentrate on the elements of computational thinking proposed by the UK Department for Education (DfE), AQA, EDEXCEL and OCR award bodies, and the barefoot computing initiative.

#### **A.2.4 Learning Styles**

Learning styles are a relatively new set of theories that propose that each of us have our own personal preferences on how we learn. These personal preferences relate to the best way in which we accept incoming information, process it and then demonstrate learning. Campbell et al. (1996) define learning styles as a certain specified pattern of behaviour according to which an individual approaches the learning experience. Likewise, Dunn et al. (1981) define learning styles as the way in which the individual takes in new information and develops new skills. Writing in the book *Contemporary Theories of Learning* (2009), Howard Gardner aligns with constructivist principles in advising that students are not an empty vessel to be filled with knowledge. Instead, due to their biological and cultural backgrounds, personal histories, and experiences, they possess different kinds of minds, with different strengths, interests, and modes of processing information. This initially complicates the teaching process and can lead to ineffectual teaching, but once considered and understood, it can actually lead to more productive teaching that reaches more students on a deeper level.

Research from psychology and education spanning over four decades support the overall proposition of learning styles. This research has, in turn, spawned a wide range of inventories which try to define and assess the various learning style dimensions.

The widespread and popular appeal of learning styles amongst educators in schools and higher education stems from the simple recognition that not all students respond equally well to the same instructional approaches, and that at face value, learning styles provide a tool for educators and their students to better align on what works best. However, in spite of the appeal and widespread use of learning styles, it remains a complex and often disputed area of education research. This pedagogy concentrates on one of the better known and well used learning style

models; Neil Fleming's VARK model focuses on the preferred mode of perceiving information within a learning context.

#### **A.2.4.1 VARK Learning Styles Model**

The VARK model is based on four perceptual modes: Visual (V), Aural (A), Read-Write (R) and Kinaesthetic (K). The VARK Model is based on the original VAK sensory modalities; however, Fleming and Baume (2006, p.5) explain that *“some students had a distinct preference for the written word whilst others preferred symbolic information as in maps, diagrams, and charts.”* Since these two preferences are not always aligned in the same person, a second 'visual' modality for read-write learners was introduced in VARK. The VARK modalities are outlined below:

1. **Visual (V)** – Visual learners prefer graphical and symbolic ways of representing information.
2. **Aural (A)** – Auditory learners prefer to learn from listening.
3. **Read-Write(R)** – Read-Write learners prefer to learn through information displayed as words.
4. **Kinaesthetic (K)** – Kinaesthetic learners prefer learning that connects them to experience and reality.

According to Allen et al. (2011), the VARK model has three basic principles:

1. Each person can learn, but may do so differently, irrespective of their level or ability.
2. Student motivation increases when their learning preferences are accommodated.
3. It is better to present new material using the learner's preferred mode of perception.

The student's preferred learning style(s) are identified by a short multiple-choice questionnaire that places them in several situations within their experience and asks them to specify their preferred action(s); this, in turn, indicates their favoured modal preference(s) (V, A, R, K). For each question, the respondent can select one or more options, or can even omit questions where they find no suitable option.

Upon questionnaire completion, respondents sum the occurrences of their preferences for each mode. This results in four scores, which represent the four modal preferences. The numerical dominance of each score reflects the strength of the modal preference.

Appendix A.2.4.4 gives an early version of the questionnaire developed by Neil Fleming at Lincoln University in New Zealand; an updated version can be found at [www.vark-learning.com](http://www.vark-learning.com).

#### **A.2.4.2 Learning Styles Focus: Adaptive or Multi-Modal**

The research on learning styles contains some debate on whether a focus on learning styles leads to genuine educational benefits and, if such a focus is to be taken, what the best implementation is. Hence, once the students' modal preferences are identified, different educational strategies can be employed. At a high-level, there are two broad approaches: adaptive or multi-modal.

In the adaptive (matching) approach, the curricula and pedagogy are tailored to the different modal preferences of the students, thereby increasing their motivation and learning performance. However, the complexity and effort involved in implementing such an approach cannot be underestimated; providing individualized curricula and pedagogy for several high school classes, managing the varying performance, while still providing meaningful feedback is incredibly challenging. From the outset, Fleming (1992, p.138) the author of VARK, acknowledges this challenge and advises *"it is simply not realistic to expect teachers to provide programs that accommodate the learning style diversity present in their classes"*.

It is, though, posited that current and future technologies can greatly support this process by catering to the different modal preferences. Advanced e-learning software that uses data analytics to build student profiles can, in turn, use artificial intelligence approaches to offer different entry points and individualised educational experiences based on affective status, past performance and modal preferences.

However, it is argued that the biggest danger with the adaptation (matching) approach, and one of the most significant sources of contention in learning styles research, is the potential for pigeon-holing or stereotyping learners, which ultimately damages their learning and development. Prevailing research opinion is that learning styles should be considered indicative, not diagnostic, and considered in relation to the learning context and content, not rigidly tailored to specific student learning styles.

In order to counter such problems, the majority of learning style theorists promote the idea that learners should develop a repertoire of styles, so that an awareness of their own preferences and abilities should not bar them from working to acquire those styles which they do not yet possess. A person can have multiple dominant modal preferences, and in any case, the less favoured modal channels should not be ignored. Instead, the more encompassing approach is to use the learning styles classification as a self-reflection tool, by which both teachers and students can understand their own natural tendencies and, armed with that knowledge, actively manage their teaching and learning.

It is typical for teachers to teach according to their preferred modal channel, not their students. It follows that this needs to be broadened to provide learning experiences that accommodate all modal preferences. Likewise, e-learning software should be developed to accommodate all modal preferences. The multi-modal approach thereby combines a mixture of approaches and teaching methods that support all modal preferences. The students' improved self-awareness then allows them to actively choose the instructional style that best fits their individual modal preference. This pedagogy, therefore, focuses on the multi-modal approach.

#### ***A.2.4.3 Supporting Students in Understanding Their Learning Style Preferences***

The VARK questionnaire can be used as a catalyst and framework for reflection and discussion of teaching and learning practices. Teachers can complete the questionnaire to understand their dominant teaching practices and modify their instruction to be multi-modal and more focused on student learning needs.

Students can complete the questionnaire and discuss with their teacher their modal preferences and appropriate learning strategies. The objective is for the teacher to support the student in knowing themselves. Then students are actively encouraged to challenge and validate their personal profiles, and to operate in a metacognitive fashion to adjust their learning behaviour.

#### A.2.4.4 VARK Learning Style Assessment Questionnaire

The following questionnaire is sourced from Fleming and Mills 1992 paper Not Another Inventory, Rather a Catalyst for Reflection. [Accessed: 06/10/2016]

<http://digitalcommons.unl.edu/podimproveacad/246>

This test is to find out something about your preferred learning method. Research on left brain/right brain differences and also on learning and personality differences suggests that each person has preferred ways to receive and communicate information.

Choose the answer that best explains your preference and put the key letter in the box. If a single answer does not match your perception, please enter two or more choices in the box. Leave blank any question that does not apply.

1. You are about to give directions to a person. She is staying in a hotel in town and wants to visit your house. She has a rental car. Would you:  
V) draw a map on paper?  
A) tell her the directions?  
R) write down the directions (without a map)?  
K) collect her from the hotel in your car?
2. You are staying in a hotel and have a rental car. You would like to visit a friend whose address/location you do not know. Would you like them to:  
V) draw you a map on paper?  
A) tell you the directions by phone?  
R) write down the directions (without a map)?  
K) collect you from the hotel in their car?
3. You have just received a copy of your itinerary for a world trip. This is of interest to a friend. Would you:  
A) ring her immediately and tell her about it?  
R) send her a copy of the printed itinerary?  
V) show her on a map of the world?
4. You are going to cook a dessert as a special treat for your family. Do you:  
K) cook something familiar without need for instructions?  
V) thumb through the cookbook looking for ideas from the pictures?  
R) refer to a specific cookbook where there is a good recipe?  
A) ask for advice from others?
5. A group of tourists have been assigned to you to find out about national parks. Would you:  
K) drive them to a national park?  
V) show them slides and photographs?  
R) give them a book on national parks?  
A) give them a talk on national parks?
6. You are about to purchase a new stereo. Other than price, what would most influence your decision?  
A) A friend talking about it  
R) Reading the details about it  
K) Listening to it  
V) It looks really upmarket
7. Recall a time in your life when you learned how to do something like playing a new board game. Try to avoid choosing a very physical skill e.g. riding a bike. How did you learn best? By:  
V) visual clues - pictures, diagrams, charts?  
R) written instructions?  
A) listening to somebody explaining it?  
K) doing it?

Summary of this page

V

A

R

K

8. Which of these games do you prefer?  
 V) Pictionary  
 R) Scrabble  
 K) Charades
9. You are about to learn to use a new program on a computer. Would you:  
 K) ask a friend to show you?  
 R) read the manual which comes with the program?  
 A) telephone a friend and ask questions about it?
10. You are not sure whether a word should be spelled 'dependent' or 'dependant'. Do you:  
 R) look it up in the dictionary?  
 V) see the word in your mind and choose the best way it looks?  
 A) sound it out in your mind?  
 K) write both versions down?
11. Apart from price, what would most influence your decision to buy a particular textbook?  
 K) Using a friend's copy  
 A) A friend talking about it  
 R) Skim reading of parts of it  
 V) It looks OK
12. A new movie has arrived in town. What would most influence your decision to go (or not go)?  
 A) Friends talked about it.  
 R) You read a review about it.  
 V) You saw a preview of it.
13. Do you prefer a lecturer/teacher who likes to use:  
 R) handouts and/or a textbook?  
 V) flow diagrams, charts, slides?  
 K) field trips, labs, practical sessions?  
 A) discussion, guest speakers?

Summary of this page                    V                     A                     R                     K

Total of both pages                    V                     A                     R                     K

Neil D Fleming  
 Director, Education Centre  
 Lincoln University, New Zealand

July 1992

#### A.2.4.5 VARK Student Guidelines

The following student hand-out is sourced from Fleming and Mills 1992 paper Not Another Inventory, Rather a Catalyst for Reflection. [Accessed: 06/10/2016]

<http://digitalcommons.unl.edu/podimproveacad/246>

**Handout sheets to help students adopt new strategies. These are used : discussion points when interviewing students, after the questionnaire has been completed.**

### V

If you have a strong preference for Visual (V) learning you should use some or all of the following:

<b>INTAKE</b> To take in the information
--

underlining  
different colors  
highlighters  
symbols  
flow charts  
charts  
graphs  
pictures, videos, posters, slides  
different spatial arrangements on the page  
white space  
textbooks with diagrams, pictures  
lecturers who use gestures and picturesque language

<b>SWOT</b> Study without tears To make a learnable package.
--

Convert your lecture 'notes' into a learnable package by reducing them (3:1) into page pictures.

Use all techniques above to do this.  
Reconstruct the images in different ways - try different spatial arrangements.  
Redraw your pages from memory.  
Replace words with symbols or initials.  
Look at your pages.

<b>OUTPUT</b> To perform well in the examination
--

Recall the 'pictures' of pages.  
Draw - use diagrams where appropriate.  
Write exam answers.  
Practice turning your visuals back into words.

You are holistic rather than reductionist in your approach. You want the whole picture. Visual learners do not like handouts, words, lectures, textbooks or assessment that hinge on word usage, syntax and grammar. You are going to watch TV.

## A

If you have a strong preference for learning by Aural methods (A = hearing) you should use some or all of the following:

<b>I N T A K E</b> <b>To take in the</b> <b>information</b>
---

attend lectures  
attend tutorials  
discuss topics with other students  
discuss topics with your lecturers  
explain new ideas to other people  
use a tape recorder  
remember the interesting examples, stories, jokes...  
describe the overheads, pictures and other visuals to somebody who was not there  
leave spaces in your lecture notes for later recall and 'filling'

<b>S W O T</b> <b>Study without tears</b> <b>To make a learnable package.</b>
---

Convert your lecture notes into a learnable package by reducing them (3:1)

Your lecture notes may be poor because you prefer to listen. You will need to expand your notes by talking with others and collecting notes from the textbook.  
Put your summarized notes onto tapes and listen to them.  
Ask others to 'hear' your understanding of a topic.  
Read your summarized notes aloud.  
Explain your notes to another 'aural' person.

<b>O U T P U T</b> <b>To perform well in</b> <b>the examination</b>
---

Talk with the examiner.  
Listen to your voices and write them down.  
Spend time in quiet places recalling the ideas.  
Practice writing answers to old exam questions.  
Speak your answers.

You prefer to have all of this page explained to you. The written words are not as valuable as those you hear. You will probably go and tell somebody about this.

## **R & W**

If you have a strong preference for learning by Reading and Writing (R & W) you should use some or all of the following:

<b>I N T A K E</b> <b>To take in the</b> <b>information</b>
---

lists  
headings  
dictionaries  
glossaries  
definitions  
handouts  
textbooks  
readings - library  
lecture notes (verbatim)  
lecturers who use words well and have lots of information in sentences and notes  
essays  
manuals (computing and laboratory)

<b>S W O T</b> <b>Study without tears</b> <b>To make a learnable package.</b>
---

Convert your lecture notes into a learnable package by reducing them (3:1)

Write out the words again and again.  
Read your notes (silently) again and again.  
Rewrite the ideas, principles into other words.  
Organize any diagrams, graphs... into statements e.g. "The trend is..."  
Turn reactions, actions, charts and flows into words.  
Imagine your lists arranged in multi-choice questions and distinguish each from each.

<b>O U T P U T</b> <b>To perform well in</b> <b>the examination</b>
---

Write exam answers.  
Practice with multiple choice questions.  
Write paragraphs, beginnings, endings.  
Write your lists (a,b,c,d, 1,2,3,4,).  
Arrange your words into hierarchies and points.

You like this page because the emphasis is on words and lists. You believe the meanings are within the words, so the talk was OK, but this handout is better. You are heading for the library.

## K

If you have a strong preference for Kinesthetic (doing) learning you should use some or all of the following:

<b>INTAKE</b> To take in the information
--

all your senses - sight, touch, taste, smell, hearing ...  
laboratories  
field trips  
field tours  
examples of principles  
lecturers who give real-life examples  
applications  
hands-on approaches (computing)  
trial and error  
collections of rock types, plants, shells, grasses...  
exhibits, samples, photographs...  
recipes--solutions to problems  
previous exam papers

<b>SWOT</b> Study without tears To make a learnable package.
--

Convert your lecture notes into a learnable package by reducing them (3:1)

Your lecture notes may be poor because the topics were not 'concrete' or 'relevant'.  
You will remember the 'real' things that happened.  
Put plenty of examples into your summary. Use case studies and applications to help with principles and abstract concepts.  
Talk about your notes with another 'K' person.  
Use pictures, photographs which illustrate an idea.  
Go back to the laboratory or your lab manual.  
Recall the experiments, field trip.

<b>OUTPUT</b> To perform well in the examination
--

Write practice answers, paragraphs.  
Role play the exam situation in your own room.

You want to experience the exam so that you can understand it. The ideas on this page are only valuable if they sound practical, real and relevant to you. You need to do things to understand.

## **B INSTRUCTIONAL TIPS TO TEACHERS IN SUPPORT OF THE HEURISTICS**

### **B.1 Heuristic 1.1: Ensure the Currency of Learning Material.**

Building on Connectivist theories that nodes on the learning network (information) are continually changing requires a new learning skillset in students. Students must be supported either by teachers or the e-learning software to understand that their existing knowledge should not be static, but must be challenged and updated to ensure it is current. Siemens summarises that *“The capacity to know is more critical than what is actually known”* (2008).

Teachers will need to teach the critical thinking and metacognitive skills for students to be able to see connections between fields, ideas and concepts, drop outdated concepts, seek out new information, and filter out extraneous information.

Teachers may also need to support this heuristic by teaching students the technical skills to select and set up push and pull technologies to keep up to date (e. g. Really Simple Syndication (RSS)), and the skills to search for and subscribe to appropriate learning content and RSS feeds.

### **B.2 Heuristic 4: Use Problem-Based Learning (PBL) to Facilitate Learning.**

As discussed in heuristic 4, for best results in problem-based learning, students should be guided by an overarching workflow on how they should approach the problem; this is aligned with the concept of macro-scaffolding discussed in heuristic 8. Clarke and Mayer (2011, p.346) suggest a seven-step process flow:

1. Use a pre-training to clarify unknown terms and concepts.
2. Define the problem and supporting problem context.
3. Learners use creative thinking to brainstorm and analyse the problem and identify plausible explanations.
4. Learners use critical thinking to evaluate the explanations and produce a coherent description of the problem.
5. Learners use metacognitive thinking to define the learning needed to solve the problem.

6. Learners engage in self-directed or guided study to undertake the learning previously identified as necessary.
7. Learners reconvene to debrief the case and share lessons learnt.

### **B.3 Heuristic 4: Selecting an Appropriately Complex and Ill-structured Problem**

To engage the learners' higher-order thinking skills, the problem used to drive learning must be suitably complex, ill-structured and preferably offer an authentic real-life scenario. In accordance with Melero et al. (2012, p.2341) it must provide enough challenge to require learners to "*think critically; analyze and solve complex real-life problems; find, evaluate and use appropriate learning resources; work collaboratively; demonstrate effective communication skills.*" Jonassen (1999, p.219) offers some guidelines in the definition of such complex, ill-structured problems; they should:

1. have unstated goals and constraints,
2. possess multiple solutions, solution paths, or no solutions at all,
3. possess multiple criteria for evaluating solutions,
4. present uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized,
5. offer no general rules or principles for describing or predicting the outcome of most cases, and
6. require learners to make judgments about the problem and to defend their judgments by expressing personal opinions or beliefs, and

It should be noted that the complexity and level of structure in the problem must consider the intended learning outcomes, learner ability and subject knowledge in order to provide a suitable challenge without creating cognitive overload.

### **B.4 Heuristic 6.2: The Ethos Behind Computational Thinking.**

In keeping with the work of Barr and Stephenson (2011), several of the characteristics that underpin the ethos of Computational Thinking are:

1. Computational Thinking does not always lead to computer solutions.
2. The first and most important step is to genuinely understand the problem or requirements.

3. Persistence is needed in working with difficult problems and an ability to handle ambiguity and open-ended problems.
4. Both teachers and students must accept that an early failed solution can often put you on the path to a successful outcome.
5. Problem-solving, and computational thinking is typically based on teamwork (figuring things out together), so successful collaborative and cooperative work is needed.
6. Self and collaborative reflection focused on the solution, and the process of creating the solution is integral to improving the solution, the development process and one's own learning.

## B.5 Heuristic 11: Use Collaborative Learning Activities

A Collaborative Learning Environment should implement a subset of the following collaborative technologies (Adapted from Clark and Mayer (2011))

Collaborative Facility	Description	Example e-learning Use
<b>Blog and Micro-blogs</b>	A website usually maintained by an individual writing regular commentary. A typical blog combines text, images, and links to other blogs, Web pages, and other media related to its topic. Visitors can comment or link to a blog.  Micro-blogs are defined by publishing short messages (approx. 140 characters) and being more dynamic in nature.	<ul style="list-style-type: none"> <li>• Learning journals.</li> <li>• Pre-class intros.</li> <li>• Post class reflections.</li> <li>• Short post-class updates.</li> <li>• Informal updates on related topics.</li> <li>• Evaluation of course effectiveness.</li> <li>• Distribution of lesson content.</li> </ul>
<b>Breakout Rooms</b>	A conferencing facility that typically supports audio, whiteboard, polling and chat. Small groups typically use it in conjunction with a virtual classroom.	<ul style="list-style-type: none"> <li>• Synchronous teamwork during a virtual classroom.</li> <li>• Small group meetings.</li> <li>• Creative thinking activities.</li> </ul>

<b>Collaborative Facility</b>	<b>Description</b>	<b>Example e-learning Use</b>
<b>Chats</b>	Two or more participants communicating over the internet at the same time by text.	<ul style="list-style-type: none"> <li>• Role play practice.</li> <li>• Group Decision making.</li> <li>• Group project work.</li> <li>• Pair collaborative study.</li> <li>• Reflection discussions.</li> <li>• Questions or comments during a virtual presentation.</li> </ul>
<b>Voice Over Internet Protocol (VOIP)</b>	Two or more participants communicating at the same time via phone services (audio) over the Internet	<ul style="list-style-type: none"> <li>• Role play practice.</li> <li>• Group Decision making</li> <li>• Group project work.</li> <li>• Pair collaborative study.</li> <li>• Reflection discussions.</li> </ul>
<b>E-Mail</b>	Two or more participants communicating at different times. The messages are received and managed at the individual's email site.	<ul style="list-style-type: none"> <li>• Group project work.</li> <li>• Instructor-student exchange.</li> <li>• Pair collaborative activities.</li> </ul>
<b>Discussion (Message) Boards</b>	A number of participants communicating at different times by posting messages that remain on the board for others to read and respond to.	<ul style="list-style-type: none"> <li>• Reflection discussions.</li> <li>• Topic-specific discussions.</li> <li>• Case study work.</li> <li>• Post class commentaries.</li> </ul>
<b>Online Conferencing</b>	A number of participants online at once with access to audio, whiteboard, polling, media displays and chat.	<ul style="list-style-type: none"> <li>• Guest Speakers.</li> <li>• Virtual classes.</li> <li>• Group project work.</li> </ul>
<b>Social Networks</b>	Individuals post pages with various media elements and link their pages to select others.	<ul style="list-style-type: none"> <li>• Finding expertise.</li> <li>• Display class agendas and objectives.</li> <li>• Icebreaker exercises.</li> </ul>

Collaborative Facility	Description	Example e-learning Use
		<ul style="list-style-type: none"> <li>• Intersession multimedia work and discussions.</li> </ul>
<b>Wikis</b>	A website that allows for the easy creation and editing of any number of interlinked Web pages. Wikis are often used to create collaborative websites that allow visitors to edit their contents. Permissions for creation / editing/viewing can be controlled or open to all.	<ul style="list-style-type: none"> <li>• Collaborative work on project document.</li> <li>• Ongoing updated repository of course information.</li> <li>• Collaborative course material construction.</li> <li>• Collaborative note taking.</li> </ul>
<b>e-portfolios</b>	An electronic portfolio is a collection of digital evidence and reflections assembled and managed by a learner or learning group, usually on the Web. The e-portfolio represents the culmination of the student or group's learning.	<ul style="list-style-type: none"> <li>• Storage and sharing of digital media and reflections as evidence of learning.</li> </ul>
<b>Cloud Office Applications</b>	Office applications hosted on the cloud and accessible over the Internet for collaborative document editing.	<ul style="list-style-type: none"> <li>• Group project work</li> <li>• Collaborative document creation / editing.</li> <li>• Immediate evaluation of lesson.</li> <li>• Lesson note taking and sharing of notes within the lesson.</li> <li>• Dynamic update of presentation material within session and presented in the same session.</li> </ul>

## **B.6 Heuristic 12: Develop and Nurture Networks to Support Learning**

Forming and maintaining a learning community places significant extra requirements on both teachers, those acting as facilitators, as well as the learners. With this in mind, the work of Rovai (2002), Brown (2001), and Blas & Poggi (2007) are synthesised into a set of guidelines for community building.

- 1. Time and support should be provided to learners for them to gain confidence with the technology, the teaching method and style of the community.**
- 2. A number of teachers and facilitators should become active participants within the learning community** in order to moderate, facilitate, exemplify expected behaviour and act as a “knowledgeable other” within the various collaborative learning interactions.
- 3. Teachers and facilitators have a critical role within the community;** however, care should be taken that they do not dominate the community, instead they should:
  - a. Model, encourage, and enthusiastically participate in the community.
  - b. Promote an atmosphere of openness, respect and trust.
  - c. Act as a knowledgeable other that teaches and scaffolds learning progress.
  - d. Provide and/or encourage substantive feedback and validation that shows that learners’ ideas and opinions are valued and respected.
  - e. Provide timely feedback and quick responses to help-requests.
  - f. Start threaded discussions and try to keep them going.
  - g. Where necessary facilitate community interactions.
  - h. Individually discourage inappropriate community behaviour.
  - i. Provide foregrounding, where discussions are held with new community members on what the community is, what is expected community behaviour, what are the benefits of community participation, etc.
  - j. Provide community reflection pieces in which learners reflect on what they have contributed to the community, what others have done to make them feel part of the community, what has been accomplished in the community and what still needs to be achieved.

4. **Community veterans and knowledgeable learners should be included in the community to support other learners.** In general, there should be a mix of knowledge and performance levels.
5. **Mutual interdependence, a sense of belonging and connectedness should be fostered within the community:**
  - a. Promote a common educational purpose that all community members are committed to and work towards.
  - b. Promote community spirit, where learners feel a sense of belonging to the community and have *“feelings of friendship, cohesion, and bonding that develop among learners as they enjoy one another and look forward to time spent together”*(Rovai 2002, p.4). This, in turn, allows students to challenge and to nurture each other in a safe learning environment.
  - c. Promote trust within the community; trust that other learners and facilitators will respond in a supportive manner, can be counted on to have the best interests of other community members at heart, and are motivated to assist them in their learning. This will reassure learners that they can safely expose gaps in their learning and seek counsel.
  - d. Promote learner interactions that are either task-driven learning activities or socio-emotional interactions designed to allow community members to bond by sharing personal information and identifying commonality in interests, experiences, goals, or values.
6. **If intrinsic community spirit is lacking, as a last resort consider whether members of the learning community should be graded on quantity, quality, and timeliness of their contributions.**
7. **Ensure a reasonable instructor to learner ratio is maintained; typically, 20 to 30 students per instructor** can be managed whilst still maintaining active participation and individual attention.

## **B.7 Heuristic 17: The Different Graphical Types Used in Educational Instruction**

In accordance with Clark and Lyons (2010), there are the following graphic types used in educational instruction:

1. **Representative graphics** are used to illustrate concrete facts, or the appearance of objects and their parts (e.g., a screen capture or a photograph of equipment). This can help ground students in reality and can be used to support case studies and problem-based learning
2. **Organisational graphics** are used to show the qualitative relationships among content, ideas, lesson topics or where parts are located in a structure. (e.g., a table illustrating relationships between concepts, a mind-map or a tree diagram).
3. **Relational graphics** are used to show quantitative relationships between variables such as bar graphs or pie charts, or a world map depicting internet penetration.
4. **Transformative graphics** are visuals that illustrate steps in a process or changes in space and time, such as a video or animation showing how to add layers in Photoshop, or visually stepping through an algorithm, or showing a time-lapse animation presenting embryo growth.
5. **Interpretive graphics** are visuals that are used to show how a system works or to make intangible phenomena visible and concrete, such as showing how data is transformed and transmitted over the Internet or drawings of molecular structures.
6. **Decorative graphics** are visuals added for aesthetic appeal or humour. This graphic type should typically be avoided.

## **B.8 Heuristic 17.1: Common mistakes in Applying Contiguity Between Words and Corresponding Graphics.**

When placing printed words near corresponding graphics, there are some common mistakes to avoid (Adapted from Clark & Mayer 2011, p.95):

1. Text being displayed at the top or bottom of the screen away from corresponding graphics.
2. Separating graphics and corresponding text due to a scrolling screen.
3. Providing instructions for a practice exercise on a separate screen.
4. Providing feedback on a separate screen to the practical activity or question.
5. Links that open a new browser window which obscures the initial screen.
6. Providing a numbered legend at the bottom of the screen for key elements of a graphic.
7. Providing text describing an animation on the other half of the screen.

## B.9 Heuristic 17.1: Tips to Reduce Unnecessary Text.

Long passages and too much text can become discouraging for many learners. This should be avoided by using multiple editing iterations to cut down the text to the bare essence. Additional, strategies include:

1. **Cut text into smaller logical chunks** that become more memorable to learners.
2. **Use bullet points** to help learners easily scan a list and break down the concepts.
3. **Use text formatting** (bold, italics and colour) to highlight important learning content. However, it is important not to overuse text formatting and to explain it ahead of time in a style guide.
4. **Careful use of rollover pop-ups<sup>9</sup>** can be used. However, rollover pop-ups are not suitable in all circumstances. They should not be used if the text is particularly important, or when it's important that the users see more than one piece of text at a time, or when an action relies on seeing the rollover text.
5. **Use a downloadable reference document** to give learners a full reference of instructional material.

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<sup>9</sup> A rollover popup is a small transient pop up message that appears when the mouse cursor touches the corresponding portion of the graphic and then disappears when the mouse is moved away.

# C 50 QUESTIONS TO HELP STUDENTS THINK ABOUT WHAT THEY THINK

This post was first published on [openncolleges.edu.au](http://openncolleges.edu.au) (Chesser 2014) and accessed [24/10/2014] from <http://www.teachthought.com/learning/metacognition-50-questions-help-students-think-think/>

Author: Lisa Chesser.

## C.1 Reflection and Collaboration

1. What do you think about what was said?
2. How would you agree or disagree with this?
3. Are there any other similar answers you can think of with alternative routes?
4. Does anyone in this class want to add something to the solution?
5. How might you convince us that your way is the best way?

## C.2 Self-Reflection

6. How did you determine this to be true?
7. Why didn't you consider a different route to the problem?
8. Why does that answer make sense to you?
9. (in response to an answer):...what if I said that's not true?
10. Is there any way to show exactly what you mean by that?

## C.3 Reasoning

11. Why do you think this works? Does it always, why?
12. How do you think this is true?
13. Show how you might prove that?

14. Why assume this?
15. How might you argue against this?

#### **C.4 Analysis**

16. How might you show the differences and similarities?
17. What patterns might lead you to an alternative answer?
18. How many possibilities can you think of and why?
19. Predict any number of results?

#### **C.5 Connections**

20. How does this relate to daily occurrences?
21. Which ideas make the most sense and why?
22. Which problems feel familiar? Why?
23. How does this relate to current events?
24. What kinds of examples make this problem workable?
25. What other problems fit this style or example?

#### **C.6 Literary Questions**

26. How did any of the characters or events remind you of yourself? Why?
27. How did the character's actions affect you? Explain.
28. If you were this character, how would the story change?
29. What surprised or confused you about the characters or events? Explain.
30. Why do you think the author wrote from this character's view?
31. What do you think the author is trying to accomplish?
32. How is the author thinking about the world?

33. How would the story change from another character's view?
34. Why do you think this story could actually happen, or not?
35. How can this story teach us something about our lives?
36. How do you think the characters resolved the major conflict in the story?
37. How would you have resolved it?
38. How would you change the end of the story and why?

## **C.7 Science and Social Questions**

39. What's the purpose for this experiment or argument?
40. Would you elaborate on the purpose of this?
41. What issues or problems do you see here?
42. What evidence or data are given that help make this worthwhile?
43. What are some of the complexities we should consider?
44. What concepts help organize this data, these experiences?
45. How can you justify this information?
46. How can we verify or test that data?
47. What details can you add to make this information feel more complete?
48. Which set of data or information is most relevant or important?
49. How is all of this consistent or inconsistent?
50. How am I seeing or viewing this information? Objectively or subjectively? Should I then change my view?

## D JAKOB NIELSEN'S TEN USABILITY HEURISTICS

Jakob Nielsen's ten heuristics for user interface design are currently being supported by the Nielsen Norman Group (1995). These heuristics were accessed [24/09/2018] from the following web page <https://www.nngroup.com/articles/ten-usability-heuristics/>

These are ten general principles for user interface design. They are called "heuristics" because they are more in the nature of rules of thumb than specific usability guidelines.

### 1. Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

### 2. Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

### 3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

### 4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

### 5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

## **6. Recognition rather than recall**

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

## **7. Flexibility and efficiency of use**

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

## **8. Aesthetic and minimalist design**

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

## **9. Help users recognize, diagnose, and recover from errors**

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

## **10. Help and documentation**

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

## E EXAMPLE TECHNIQUES TO REPRESENT COMPUTATIONAL THINKING

The following example techniques to represent Computational Thinking are sourced from Curzon et al.(2014)

Accessed [10/July/2015] from <http://eprints.soton.ac.uk/369594/>

Concept	Examples of Techniques
Algorithmic Thinking	<p>Writing instructions that if followed in a given order (<i>sequences</i>) achieve a desired effect;</p> <p>Writing instructions that use arithmetic and logical operations to achieve a desired effect;</p> <p>Writing instructions that store, move and manipulate data to achieve a desired effect; (<i>variables</i> and <i>assignment</i>)</p> <p>Writing instructions that choose between different constituent instructions (<i>selection</i>) to achieve a desired effect;</p> <p>Writing instructions that repeat groups of constituent instructions (<i>loops/iteration</i>) to achieve a desired effect;</p> <p>Grouping and naming a collection of instructions that do a well-defined task to make a new instruction (<i>subroutines, procedures, functions, methods</i>);</p> <p>Writing instructions that involve subroutines use copies of themselves to achieve a desired effect (<i>recursion</i>);</p> <p>Writing sets of instructions that can be followed at the same time by different agents (computers or people) to achieve a desired effect (<i>Parallel thinking and processing, concurrency</i>);</p> <p>Writing a set of rules to achieve a desired effect (<i>declarative languages</i>);</p> <p>Using a standard notation to represent each of the above;</p> <p>Creating algorithms to test a hypothesis;</p> <p>Creating algorithms that give good, though not always the best, solutions (<i>heuristics</i>);</p> <p>Creating algorithmic descriptions of real world processes so as to better understand them (<i>computational modelling</i>);</p> <p>Designing algorithmic solutions that take into account the abilities, limitations and desires of the people who will use them;</p>

Evaluation	<p>Assessing that an algorithm is fit for purpose;</p> <p>Assessing whether an algorithm does the right thing (<i>functional correctness</i>);</p> <p>Designing and running test plans and interpreting the results (<i>testing</i>);</p> <p>Assessment whether the performance of an algorithm is good enough;</p> <p>Comparing the performance of algorithms that do the same thing;</p> <p>Making trade-offs between conflicting demands;</p> <p>Assessment of whether a system is easy for people to use (<i>usability</i>);</p> <p>Assessment of whether a system gives an appropriately positive experience when used (<i>user experience</i>);</p> <p>Assessment of any of the above against set criteria;</p> <p>Stepping through algorithms/code step by step to work out what they do (<i>dry run / tracing</i>);</p> <p>Using rigorous argument to justify that an algorithm works (<i>proof</i>);</p> <p>Using rigorous argument to check the usability or performance of an algorithm (<i>analytical evaluation</i>);</p> <p>Using methods involving observing a system in use to assess its usability or performance (<i>empirical evaluation</i>);</p> <p>Judging when an algorithmic solution is good enough even if it is not perfect;</p> <p>Assessing whether a solution meets the specification (criteria);</p> <p>Assessing whether a product meets general performance criteria (heuristics)</p>
Decomposition	<p>Breaking down artefacts (whether objects, problems, processes, solutions, systems or abstractions) into constituent parts to make them easier to work with;</p> <p>Breaking down a problem into simpler but otherwise identical versions of the same problem that can be solved in the same way (<i>Recursive and Divide and conquer strategies</i>)</p>

Abstraction	<p>Reducing complexity by removing unnecessary detail;</p> <p>Choosing a way to represent artefacts (whether objects, problems, processes or systems) to allow it to be manipulated in useful ways;</p> <p>Hiding the full complexity of an artefact, whether objects, problems, processes, solutions, systems (<i>hiding functional complexity</i>);</p> <p>Hiding complexity in data, for example by using data structures;</p> <p>Identifying relationships between abstractions;</p> <p>Filtering information when developing solutions;</p>
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Generalisation	Identifying patterns and commonalities in problems, processes, solutions, or data.  Adapting solutions or parts of solutions so they apply to a whole class of similar problems;  Transferring ideas and solutions from one problem area to another
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## REFERENCES

Removed for brevity and to reduce duplication. Please refer to thesis Reference section for a full set of references.