Real-life scenario blended teaching approach for nurturing inquisitive learning of central nervous system in medical students

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Running title. Real-life scenario blended teaching-learning approach

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Snapshot

In this report, a novel teaching methodology, 'real-life scenario (RLS) blended teaching' is described and its effectiveness in facilitating inquisitive learning in undergraduate medical students was evaluated. Students exposed to RLS sessions blended with multiple assignments, peer discussions, multiple formative assignments, and facilitator feedback sessions performed well in the summative assessments compared to those exposed to RLS sessions and assignments or exposed to traditional teaching alone. Students preferred active teaching-learning techniques over the traditional method.

Abstract

Among the various systems taught in the preclinical phases, the nervous system is more challenging to learn than other systems. In this report, a novel teaching methodology, 'real-life scenario (RLS) blended teaching' is described and its effectiveness in facilitating inquisitive learning in undergraduate medical students was evaluated. This mixed-method study was conducted among three groups (Group-1; *n*=83, Group-2; *n*=85, and Group-3; *n*=79) of undergraduate medical students (18-20 years) in the neurology and behavioral sciences module. RLS was presented to students in the form of demonstrations, role-plays, videos, and group activities. Group-1 students underwent traditional teaching-learning sessions. Group-2 students underwent RLS blended sessions and were provided with multiple mini-assignments in a vignette format. Group-3 students received RLS blended sessions, multiple mini-assignments, peer discussions, multiple formative assessments, and facilitator feedback sessions. The student performances on different exams were compared in terms of their Group, and their perceptions of RLS were documented. Students exposed to RLS sessions blended with multiple assignments, peer discussions, multiple formative assignments, and facilitator feedback sessions performed well in the final summative assessments (67.87%) compared to those exposed to RLS sessions and assignments (50.21%) or exposed to traditional teaching alone (50.34%). RLS sessions increased students' curiosity and motivated them to learn the subject well. RLS sessions stimulated student interest and facilitated their learning. RLS along with effective use of multiple assignments, formative assessments and/or feedback sessions significantly improved student learning. This demonstrates the effectiveness of this active method in teaching various subjects with appropriate modifications.

Keywords

Physiology, central nervous system, real-life scenario demonstration, assignment, formative assessment

Introduction

Learning physiology is not as easy as that of other medical subjects in the initial preclinical phases of studies [1, 2]. Among the various systems taught in the preclinical phases, the central nervous system is more challenging to learn than other systems [3]. Therefore, in many medical schools, this system is introduced towards the end of the two years of preclinical curriculum. This puts students in a better situation as they have learned all the other systems before being exposed to the central nervous system (CNS).

Learning the CNS requires visualizing and understanding several concepts, including causal reasoning [3]. Understanding this system requires intention, intuition, and practice. Becoming a master in each of the CNS topics and relating them with clinical situations is also demanding. In addition, although students obtain an opportunity to learn several subjects in an integrated curriculum, each subject's contact hours may not be the same as that of the old traditional system. In this context, it is pertinent to develop novel methodologies that enhance students' classroom learning in a student-centered way. These novel strategies must be successful in delivering subject content effectively to students. Moreover, such methods must evoke critical thinking among students, making them lifelong learners. This can be achieved by having them participate in role-playing, acting, demonstrations, and game activities during a theory teaching session. Reports indicate that such methods create a positive class environment and influence students' learning in the classroom [4-7].

Learning physiology will be more engaging when there is an opportunity to bring real-life situations into the teaching-learning process. Several topics in the CNS provide an opportunity for these types of learning. Real-life scenario (RLS) blended teaching brings situations that students encounter in their everyday lives into the classroom and blends them with CNS teaching and learning. This was developed to make learning more realistic and student-centered. Additionally, each student-centered activity is designed to be similar to how it is experienced in real life. Some examples are activities based on touch, reflexes (the withdrawal reflex, specifically removing body parts from painful stimuli), conscious voluntary activities, balance, and recalling someone's name. Therefore, students can relate classroom learning with things that happen in their bodies and associate it with their day-to-day lives. In recent years, clinical case scenario-based teaching methods have been adopted in several disciplines, including physiology (8, 9).

RLS teaching can also be considered a modified case-based learning wherein, instead of a clinical case, a physiological process that happens in our body or an activity that we do in our day-to-day life is demonstrated/acted/role-played in front of students or shown to them in the form of videos to generate curiosity and interest. Moreover, these activities will also have an active learning component added. According to a report, teaching a concept by relating it to day-to-day activities promotes learning [10]. It is also important to help students understand the underlying mechanisms and significance of a normal physiological process before presenting them with clinical case scenarios. Once they grasp the normal physiological process, relating this with the clinical scenarios will be much easier. Therefore, we hypothesise that RLS blended lectures will help students relate to their body mechanisms, evoking their interest in learning CNS concepts and leading to enhanced learning.

Several studies have established active learning effectiveness, such as small homework assignments compared to passive learning, wherein a student merely sits and listens to a lecture [11-13]. Similarly, formative assessment is an important activity in contemporary medical education and is reported to produce learning gains in a range of educational settings [14-18]. Blending the above two activities (assignments and formative assessments) with the RLS method was also tested in the current study. The intention is that since the real-life scenarios are very realistic, any student can personally experience them. Blending this with physiology teaching, including multiple mini-assignments, peer discussions, formative assessments, and feedback, may help students to become active learners and facilitates their learning. In the current study, along with describing a novel teaching methodology to undergraduate medical students (RLS blended teaching), we compared the effectiveness of didactic lectures vs the application of RLS blended teaching with multiple mini-assignments, with and without peer discussions, multiple mini formative assessments, and feedback sessions, in facilitating inquisitive learning of CNS- Physiology. Students' perceptions of this combined novel teaching and learning strategy were also documented and reported.

Methodology

Study design, study population, and educational context

This mixed-method study was conducted among second-year undergraduate medical students (18-20 years) of Ras Al Khaimah Medical and Health Sciences University, Ras Al Khaimah, UAE. The Institutional Research Ethics Committee approved the procedures used in the study (RAKMHSU-REC-139-2018-F-M). Preclerkship courses (Years I and II – Semesters I to IV) of MBBS follow an integrated modular curriculum. The current study was conducted in the neurology and behavioral sciences module (8 weeks' duration), which was taught as the last module of MBBS Year-2. This is a 9-credit course, which includes both theory and practical components. The Physiology theory sessions account for 18 hours of classroom study, including active learning sessions; the same faculty taught all the topics. A total of 247 students were involved in the study and they belonged to three groups; Group-1 (n=83), Group-2 (n=85), and Group-3 (n=79) (Fig 1).

Teaching-learning context and study plan for Group-1, 2 and 3

Group-1 was taught by using the traditional methods of the teaching-learning process. This included didactic lectures using PowerPoint (ppt) presentations and blackboard teaching (Fig 1). RLS blended sessions were incorporated for teaching both Group-2 and 3 (Fig 1). RLS was presented in the form of student-involved demonstrations, role-plays, videos, and group activities. The majority were presented as icebreakers during regular didactic or active learning sessions. Scenarios were presented for the following topics: *a)* tactile sensation (touch), *b)* reflexes, *c)* fine voluntary activity, *d)* motor coordination, *e)* initiation, timing, and scaling the movements, f) emotion *g)* speaking the heard and written word, *h)* learning and memory, and *i)* reasoning and working memory. These were presented in 10 different teaching sessions as part of the neurology and behavioral sciences module's regular physiology teaching.

Group-2, Students underwent RLS blended demonstration sessions as described below. They were then given multiple mini-assignments (RLS-based vignette-type scenarios and related questions; Table 1) on the same topics, and this process was carried out throughout the module. The questions under each RLS scenario were of objective type, short answer, RRE, essay, and/or questions related to drawing diagrams such as neural circuitry for a reflex/tracts/brain region (Table 1).

Group-3 students also underwent RLS blended sessions, and after each session, they were given RLS-based scenarios and questions as assignments similar to Group-2. Group-3 was instructed to discuss the same with their classmates (TBL team-based learning group members) while answering assignment questions. Each question was sent to the students and included a deadline for submitting their work online and on time. These were collected either by e-mail or through Google classroom, were checked for correctness, and then were returned with specific individual feedback if needed. Group-3 also received unsupervised online tests to assess the students' knowledge. After each formative assessment, a feedback session was arranged using online platforms (Google Meet) to give students specific feedback. Thematic analysis of Group-3 student descriptions on the effectiveness of the RLS method was also performed. All three Group students' Physiology scores in the continuous and final summative examination of neurology and behavioral sciences were noted and compared.

Real-life scenario presentation

***a)* Tactile sensation (Touch sensation).**

This session was conducted during the teaching session on the sensory system (dorsal column tract discussion).

Student involved activity.

This was done as an icebreaker (a method for learners and educators to become acquainted before starting a teaching and learning session) before the dorsal column tract teaching session. At the beginning of this session, a student volunteer was invited to the dais. He was asked to stand facing the class and close his eyes. The facilitator then touched the skin over the volunteer's palm's dorsum using a wisp of cotton (Fig 2A). The volunteer was instructed to raise their hand once they felt the touch sensation; the same was repeated on the other hand. The volunteer was then asked to locate the area of stimulation to demonstrate the localization of stimuli. The volunteer was able to locate the area stimulated precisely. In this context, lateral inhibition connection was also demonstrated (Fig 2B). Three additional volunteers were asked to come over to the stage, and they were asked to stand as depicted in Fig 2B. The class was informed that the three volunteers represented three sensory units (Fig 2C). The middle student was asked to touch the adjacent students, as seen in the picture (Fig 2B). It was explained to the students that when a middle sensory unit is stimulated (Fig 2C, sensory unit-b), an action potential will be transmitted through it. Through this neuron's bilateral connections, adjacent neurons will be inhibited. Therefore, the stimulus is perceived as coming from only one fiber leading to localization of the stimulus.

b) **Reflexes (knee jerk and withdrawal reflex)**

Multiple activities were performed during the teaching session that focused on types of reflexes and their significance in posture regulation.

Student involved activity and facilitator role-plays.

One student volunteer was asked to sit on a table placed on the dais for this activity. To demonstrate the reflex response (knee jerk), the patellar tendon was later tapped using a knee hammer (Fig 3A). Students were asked to observe the lower leg's sudden kicking movement in response to the sharp tap. Subsequently, the facilitator imitated an exaggerated knee jerk and pendular knee jerk in front of students in the form of role-plays. This was done to differentiate what happens to the knee jerk when there are upper motor neuron and cerebellar lesions, making the discussion clinically relevant. Students were asked to draw the neural circuitry for this reflex while the facilitator drew the same on the blackboard. The functions of various components of the reflex and their roles in determining the muscle's length were discussed.

Following this, with the help of another student volunteer, the withdrawal reflex was demonstrated. The student was asked to respond if a painful stimulus was applied to the hand (Fig 3B and C). Thus, the withdrawal of the hand in response to a painful stimulus was demonstrated to the whole class. The class was told that the same response would involuntarily happen if one touched a hot object. With the help of another student, a volunteer withdrawal reflex response in the lower limb was demonstrated. This student was asked to show the response when they accidentally stepped on a nail. The neural basis for the above response (crossed extensor reflex) was discussed along with the relevant neural circuitry. This reflex strategically controls body posture when there is a sudden change in the body's center of gravity. It was also explained to students using relevant diagrams/neural circuitry with blackboard or ppt presentations.

***c)* Fine skilled voluntary activity**

This was done as a part of motor system discussion, specifically, while discussing the tract that controls the fine skilled voluntary activity (the 'corticospinal tract'). It was performed as an icebreaker, preceding the discussion on the origin, course, and termination of the corticospinal tract and its functions.

Student involved activity.

The facilitator requested one of the student volunteers to come over to the dais and write her name on the board (Fig 4A). The whole class was asked to carefully watch how the student maneuvered the marker (Fig 4B and C) and to watch their own finger movements while taking down the lecture notes.

***d)* Motor coordination**

Student-involved activities and facilitator role-plays were conducted as a part of teaching sessions that discussed the cerebellum and its motor control.

Student involved activity.

To first demonstrate the functions of various lobes of the cerebellum, a student volunteer was asked to walk in a straight line. The other students watched the volunteer's gait carefully. It was explained that we walk without any swaying due to the normal functioning of the vestibulocerebellum. Later, the facilitator explained the functions of the vestibulocerebellum. As a clinical note, the facilitator also demonstrated a 'drunken gait' as a role-play. Second, another student volunteer was then invited to the dais and asked to touch the facilitator's finger, holding one-hand distance from the student volunteer (Fig 5A). The student volunteer was then asked to touch their nose (Fig 5B). This was done rapidly, and the volunteer was later asked to repeat the actions using their other hand. While the student was doing the activity correctly, the class was told that this was called motor coordination (the students were then given time to perform this activity by themselves). As a clinical note, the facilitator demonstrated an 'intentional tremor' as role-play. The class was informed that they could perform this activity without any 'intentional tremor' due to the spinocerebellum's appropriate functioning, as this lobe of the cerebellum functions as a comparator. Third, as an attempt to demonstrate the cerebellum's timing function, specifically the cerebrocerebellum, another student volunteer was invited to the dais to perform a repeated alternating movement following the facilitator's instructions (Fig 5C). This was done with both hands, and the class was then told that when there is a lesion in cerebrocerebellum, dysdiadochokinesia occurs.

e) **Initiation, scaling, and timing of movements**

This was done as a part of the basal nuclei teaching session. During this session, multiple student demonstrations and faculty role-play were performed to apprise students of the basal nuclei's motor control role.

Student involved activity.

To demonstrate the 'initiation of voluntary motor activity, a student volunteer was requested to sit on a chair placed in front of the class (Fig 6A). The volunteer was then instructed to get up quickly (Fig 6B); the response was immediate. The students were informed that initiating such movements (getting up from the chair) is one of the basal nuclei's primary functions. This was done as an icebreaker for a discussion on direct and indirect circuits. The explanation of how these pathways control voluntary motor activity was performed using a PowerPoint (ppt) presentation containing a flow chart of these circuits. Akinesia was demonstrated to the students as a role-play by the facilitator.

To demonstrate the 'scaling function', the entire class was asked to write the English alphabet letter 'a' on the notebook (Fig 6C), and one representative from the class was asked to come over to the stage and write the same letter on the board (Fig 6D). After the student wrote 'a' on the board, their notebook was brought near the blackboard, and students were asked to compare the size of the 'a' written in the notebook to the one written on the blackboard. The class was told that basal nuclei are responsible for this scaling function, such as deciding the size of the letter 'a' in writing it on a notebook versus a blackboard. The same concept was also demonstrated in another real-life demonstration. As shown in Fig 6E, when someone is asked to catch a small ball, the hands are subconsciously manipulated accordingly, i.e., small in size (purple arrow; Fig 6E). However, whenever the ball's size increases, a change is also brought about subconsciously in the hands (red arrow; Fig 6F).

To demonstrate the basal ganglia's 'timing function', two students were invited to the dais, as shown in Fig 6E. Initially, one of the students was instructed to throw a ball (slowly), and the other was instructed to catch it. The student was then instructed to throw it fast, and the other was again instructed to catch it. The whole class was told to carefully watch the hand movement speed of the student catching the ball. As the student caught the slow ball, their hand movements were very slow. However, when they received the ball thrown faster, their response was also faster. Abnormalities in the initiation, scaling and timing of voluntary movements were also elaborated in the context of Parkinson's disease.

***f)* Speaking the heard and written word**

This was done as a part of a discussion on association areas of the cortex and their functions. The act was designed as an icebreaker that preceded the discussion of the brain's sequence of impulse flow when someone speaks a written word (Fig 7A).

Student involved activity.

To demonstrate how one speaks a written word, a student volunteer was invited to the dais and asked to read the word written on the board (Fig 7B). The student could read it clearly without any delay (Fig 7B). To demonstrate the sequence of impulse flow in the brain when someone speaks a heard word (Fig 7C), another student volunteer was asked to repeat the word spoken by the facilitator. All neural circuitries for both scenarios (Fig 7A and C) were discussed in the context of various aphasias using ppt presentations.

***g)* Emotion**

This was done as a part of a teaching session on the functions of the hypothalamus and emotions. This was planned in the form of a video presentation and was done as a part of a lid opener that proceeded a session on the neural basis of emotion.

Video presentation.

A video of a lion chasing giraffe was presented to the students. It was a small part of a full video documentary initially broadcast by the BBC [19]. The context of this discussion is as follows. Emotions make an animal immensely more successful in the struggle for existence. For example, if food is a source of pleasure to an animal, the drive to pursue food is strengthened. In anticipation of this pleasure, the animal vigorously searches for food. If it is a carnivore (such as a lion), the animal becomes very aggressive when confronted with a potential food source: the zebra. On the other hand, looking at it from the viewpoint of the victim (the zebra), the emotion of fear increases its running speed, which is likely to facilitate a safe escape. Thus, using this video, how the emotions of pleasure, aggression, and fear aid survival were demonstrated to students while discussing the 'neural basis of emotions'.

***h)* Learning and memory**

This was done while teaching the physiology of learning and memory.

Student involved activity.

All students in the class participated in this activity. In the middle of a didactic session, a certain ppt containing images of different objects (such as apples, bananas, and coconuts) was shown to students. Later, they were asked to recollect what and how many objects were presented on the ppt. To demonstrate short-term memory, a question such as "how many objects were presented in the previous slide?" was asked. To demonstrate declarative memory-episodic memory, a student volunteer was asked to share the place they visited during the last winter break. To explain semantic memory and differentiate it from declarative memory, another student was asked to recite the country's traffic rules. To demonstrate a real-life example of long-term memory, an additional student volunteer was asked to say his/ her name. The neural basis (long-term memory) for the student's immediate response (the name) was explained to the students. The brain regions responsible for learning and memory and the different mechanisms that underlie short-term and long-term memory formation were highlighted. An explanation of why this information is not forgotten (conversion of short-term to long-term memory due to repeated trials) was also given.

***i)* Reasoning and working memory**

This was done in the form of a mini-interview in a session allotted for discussing different brain lobes' functions, particularly the frontal lobe. One student was asked to share their 'Instagram' password with the whole class to demonstrate brain function reasoning. Of course, the student's answer was an emphatic 'NO'! The reason why the student answered "NO", and the role the prefrontal cortex played in the student's answer was then explained. For working memory, the students were asked to perform a simple math calculation. The difference between other memory forms and working memory was also highlighted.

Students' perceptions of the RLS method

This was determined by asking students (Group-2 and 3) to respond to a validated closed-ended questionnaire that included items focusing on the utility of this teaching-learning approach to facilitate various learning skills. Respondents answered items using a 5-point Likert scale (where 5 = strongly agree, 4 = agree, 3 = uncertain, 2 = disagree, and 1 = strongly disagree). The reliability of this was tested by doing an appropriate statistical test. Students were also requested to describe their opinions on how learning took place in the RLS blended sessions.

Thematic analysis

The student descriptions (Group-3) on the RLS method were first listed one after the other for getting familiarized with their opinion. In order to get a condensed view of these descriptions' codes were identified. Using these codes, a general pattern of students' opinions was formed. At this stage, any overlapping patterns were clubbed and initial themes were generated. Any overlapping themes were clubbed and final themes were unidentified. Themes, their definitions with student quotes relating to a theme were reported.

Statistical analysis

Perceptions of students concerning the RLS method are presented as percentages. Summative examination physiology scores of students are also represented as the mean ± SE. One Way ANOVA and post hoc Tukey's test was performed to determine the difference in students' mean scores for both Groups. GraphPad Prism software was used to analyze the data.

Results

Comparison of student scores in continuous and final assessments

The mean scores obtained for the students who experienced didactic teaching-learning sessions (Group-1) was 27.49±15.89% in the continuous assessment (Fig 8A). However, Group-2 students who were exposed to RLS blended sessions scored 57.23±22.45% which was significantly higher compared to Group-1 (Fig 8A). This pattern was repeated with Group-3 who experienced RLS sessions blended with multiple assignments, peer discussions, multiple formative assignments, and facilitator feedback sessions. Their mean score was 58.42±17.05% which was significantly higher ($p<0.0001$) compared to Group-1 scores (Fig 8A).

The mean physiology score obtained for the students in Group-1 was 50.34±21.68% in the final summative assessment (Fig 8B). Group-2 scores were also found to be similar compared to Group-1 (50.21±20.18%) in the final summative assessment (Fig 8B). However, Group-3 students scored significantly higher, with a score of 67.87±19.16%. One-way ANOVA and post hoc Tukey's test revealed Group-3 scores were significantly higher compared to both Group-1 and Group-2 student scores. ($p<0.0001$) (Fig 8B).

Student perceptions on RLS sessions blended with multiple mini-assignments (Group-2).

Student perceptions of this Group are presented in Figure 9 and Table 2. This covered the following aspects of the RLS teaching method. It's novelty, increasing students' interest in CNS, relating CNS role in everyday life, ability in engaging students, making students understand CNS topics, motivating them to learn CNS, evoking critical thinking, beneficial for exams, inducing collaborative skills and utility of this method in teaching other Physiology topics or subjects (Figure 9). To questions related to specific sessions conducted as a part of RLS sessions, 85% of the students responded positively for almost all sessions (Table-2).

Student perceptions on RLS sessions blended with multiple mini-assignments, peer discussions, formative assessments, and feedback sessions (Group-3).

Student perceptions of this Group are presented in Figure 10 and Table 3. The following aspects of RLS method were covered in this questionnaire. It's novelty, increasing students' interest in CNS, relating CNS role in everyday life, ability in engaging students, making students understand CNS topics, motivating them to learn CNS, evoking critical thinking, beneficial for exams, inducing collaborative skills, facilitating peer discussion, the utility of this method for teaching other Physiology topics or subjects, repeated revision of topic, self-reflecting student learning and facilitation learning for summative examinations (Figure 10). Student opinions on individual RLS sessions were impressive, as 90% responded that each of the RLS examples and teaching sessions was highly relevant and appropriate for the concepts discussed (Table-3).

Comparison of Group-2 and 3 student perceptions on RLS blended sessions.

A comparison of student perceptions of RLS blended teaching sessions revealed that both Group-2 and 3 had similar opinions on various aspects of the RLS method. Among the 17 items of the survey, many items received very positive responses from students. To a question about their views on the effectiveness of the RLS method in relating CNS to everyday life 72% of Group-2, students responded positively but, 20% were 'not sure' about it (Fig 9; Q1). On the other hand, 92% of Group-3 students responded positively to the same question, while just 2.9% selected 'not sure' (Fig 10; Q1). To a question on whether RLS blended teaching is an innovative method or not, both the group students responded positively, and their responses (Group-2; 95% and Group-3; 91%) were comparable (Fig 9; Q2, Fig 10; Q2). Both Group-2 and 3 students (92% and 90% respectively) responded positively to a question on the effectiveness of RLS demonstrations in making them better understand CNS topics (Fig 9; Q6, Fig 10; Q6). To a question on whether RLS helped them in recollecting the concepts during studies/exams, both the groups responded positively (Group-2; 79% and Group-3; 85%) and their responses were comparable (Fig 9; Q10, Fig10; Q10). Both groups (Group-2; 91% and Group-3; 84%) were fully in agreement that this method was very effective for learning complex concepts of the central nervous system (Fig 9; Q11, Fig 10; Q11). Both the groups' responses were also comparable (Group-2; 83% and Group-3; 85%) when asked about their opinion on the RLS method's effectiveness in breaking the monotony of the didactic lectures (Fig 9; Q12, Fig 10; Q12). Also, when obtaining their opinion on the effectiveness of scenario-based question discussions in helping them better learn CNS, both the groups responded positively (Group-2; 82% and Group-3; 86%) and their responses were comparable (Fig 9; Q13, Fig 10; Q13). Disagreement and not sure responses were significantly less for all of the above-discussed questions but, questions on the role of RLS in positively influencing communication skills, literature searches, and selection of relevant resources/information had a significant number of disagreement/not sure responses, and these were comparable between Groups-2 and 3 (Figure 9 and 10).

Thematic analysis

Group-3 student descriptions on the effectiveness of the RLS method broadly fall into nine themes. They were innovative initiative, enjoyable experience, mental grasp, effective engagement, intrinsic motivation, experience retrieval, helpful approach, strong positive feeling, and appreciativeness. These themes and their definitions with students' samples quotes were represented in Table 4.

Discussion

Real-life scenario blended teaching was designed to nurture inquisitive learning in students. It evokes interest and curiosity among the students as they start to think about how a physiological process occurs in the body. It is evident from the student responses that RLS blended teaching effectively evoked curiosity among students, and they appreciated the method. It was reported earlier that to increase student understanding teachers must reduce the amount of factual information that the student needs to memorize, reduce the passive lecture format and help students become active independent learners and problem solvers [20]. The current study is relevant in this context, and the method positively influenced the student learning process in both groups. However, the Group that received RLS blended with multiple mini-assignments, peer discussions, formative assessments, and feedback sessions performed well in the final examination compared to the others.

It was evident from the results that the mean score of students who underwent the traditional mode of teaching was less compared to other group scores during the progress examination. This indicates that RLS could bring a positive influence on the learning of both Group-2 and 3. Although Group-2 mean score was much better compared to Group-1 in the continuous progress examination, the student's performance was just equal to that of Group-1 students (average score; ~51% in physiology questions) in the final examination. As evident from Figure 9 and Table 2, the Group-2 members' perceptions of RLS sessions were extremely positive. They liked the method, but it was not reflected in their final examination scores. A follow-up analysis that gathered information after discussions with these students revealed that the lack of follow-up, discussion, and feedback sessions after posting the assignment questions could be a possible explanation for Group-2 performance. Considering this, for Group-3, assignment correction, small group discussion, feedback, and formative assessments were added in addition to RLS demonstrations, and it is evident from the results that the above interventions increased their physiology performance in final exams. It is worth noting that the 'FAIR' principles (Feedback, Active learning, Individualised, Relevant) proposed by Harden and Laidlaw were followed for Group-3; however, they were not introduced in the same order as they have been proposed [21]. As described earlier, the RLS activity was the first event wherein students could participate in the same via active participation and learning. To reinforce what they have learned from this and to have active involvement of the students, multiple assignments were given at regular intervals to make the learning a continuous process. Submitted assignment questions were answered by different students differently as per their reference and understanding; therefore, some sort of individualization was present in the whole process. Additionally, as per their submission, feedback was provided, which added to each student's individualized treatment. As described earlier, each physiology teaching-learning session that included an RLS session was relevant for their future clinical training and practice as a doctor.

The Group-3 student's final examination scores demonstrate that the current method induced in-depth learning among students. There could be multiple reasons for this finding and the students' overall satisfaction with the RLS method. This may include the role of active strategies such as RLS's influence, student participation in active learning, multiple assignment submission and correction, testing for learning-formative assessments, and feedback sessions. Generally, medical students are bright, extremely motivated, and enthusiastic learners. But too much teaching included with numerous didactic sessions in less time may not be effective [14]. Even after spending significant time lecturing on various topics, this could be one of the possible reasons for the poor performance of Group-1 students in the continuous examination. Individual differences in the learning abilities of two different groups in this module could be other possible reasons for the above finding. The time they received to prepare for the final examination helped them to achieve almost similar scores to that of other groups and this once again ascertains the above statement.

Students try to remember the lecture's factual information, but retention of acquired knowledge is short-lived most of the time, and it could be possible that the grades do not correlate with critical thinking abilities [20-23]. In contrast, an active learning strategy, such as RLS was used in the current study. It is a well-known fact that with tremendous demands on time and attention, medical students must choose where to focus their energies and attention most efficiently. Moreover, such active learning strategies would help them decrease their efforts in selecting what to study. Reports demonstrate that the class activities promote better understanding and foster learning [4, 5, 8]. Active learning strategies and student-centered teaching significantly influence students' understanding of various subjects [24, 25] Multiple types of active learning strategies have been used in medical schools [26], and the majority of them are known to contribute to enhanced learning for students [27]. It was found that residents

(Family and Community Medicine, Internal Medicine, and Paediatrics) in the active learning session perceived themselves and were observed to be more engaged with the session content and each other than residents in didactic sessions [28]. Several institutions have focused on replacing traditional didactic lectures with active learning in the flipped classroom [29]. This type of format has been indicated to improve the quality of student learning and student engagement [29]. On the other hand, integrating traditional lectures and active learning methods has also been beneficial [30, 31]. The current RLS method can be considered in this category. In the RLS method, the demonstrations were presented as icebreakers. Students were given short periods of didactic lectures followed by breaks in which RLS sessions were conducted to reinforce the materials just presented to take them to their learning context.

As evident from student responses, RLS method improved their performance, increased their alertness, and promoted engagement. Moreover, a comparison of student perceptions of RLS blended teaching sessions revealed that several aspects of the RLS have been much liked by students. These are the following and it's worth discussing them. RLS method's potential in relating CNS to everyday life, its novelty, its usefulness in making them better understand CNS topics, its role in helping them recollect the concepts during studies/exams, its efficacy in helping students learn complex CNS concepts, its power in breaking the monotony of the didactic lectures, and advantage of scenario-based question discussions in helping them better learn CNS. Students' responses on the specific RLS method used for teaching CNS also positively influenced students wherein Group-2 students liked 'reflexes demonstrations' the most as indicated by 96% positive responses from students on questions related to the specific RLS method (Table 2; Q2). On the other hand, 'the tactile sensation demonstration' was liked by Group-3 students as indicated by 98% of the students responding positively to that question (Table 3; Q1). Similar types of engaging lectures were observed to improve student performance [32-34].

Mounting evidence suggests the importance of 'testing for learning' with a 'formative assessment'. This has been conducted in several forms, such as the well-known television game "Who Wants to Be a Millionaire?" format, [15] unsupervised online quizzes, [16] and structured verbal comments [35]. Almost all of the reports suggest that formative assessments produce learning gains in a wide range of educational settings and must be an important medical education activity. As described earlier, the formative test that we conducted was also an unsupervised online test, and it was performed multiple times, which would have facilitated student learning in Group-3.

It has been documented that the academic achievements of students who receive effective feedback are considerably higher than those of students who do not receive any feedback at all [21]. Some of the satisfaction studies conducted among undergraduate students revealed that one of the most common complaints among students is that they do not receive meaningful feedback. According to Hattie and Timperley, [36] the most powerful thing teachers can do to enhance their students' academic performance is to provide them with effective feedback. Meaningful individual feedback sessions with Group-3 students could be the other reason for the positive outcome found with Group-3.

Furthermore, RLS and related additional activities clearly enhanced the student's long-term understanding of various concepts of neuroscience. This is interesting and needs elaboration. In a traditional didactic lecture session, the facts or information's are provided to students for a specific duration with less time for topic related associated activities and rehearsal. It is possible that this factual information's fade away over a period of time, mainly due to the fact that they are still in the brain's short-term memory storage processing. The possibility of forgetting or unable to remember is maximal at this stage, as it has not been converted to long-term memory. It is the lack of topic related associated activities and rehearsal prevents the information being converted to long-term memory. RLS-blended teaching is pertinent in this context. During RLS blended teaching sessions, actual life scenarios were included. Moreover, following every RLS blended teaching sessions, students receive assignments related to that topic which they needs to answer and share it with their teacher for feedback, participate in peer discussions, undergo mock exams related to the same topic, receive feedback on their performance, above all, get an opportunity to recollect the events takes place in the class during their private study time, during revisions and exams. All of these processes facilitates the information that a student learnt in the classroom to become a long-term memory through a process called consolidation. Similar to encountering new events or knowledge, which will stimulate the formation of a short-term memory. After associating that new knowledge with existing knowledge or by repeating and rehearsing the knowledge in multiple ways, such knowledge will be consolidated to form long-term memory (37). A long-term memory can last for a few minutes or for one's entire life (38). It is evident from the current results that RLS blended teaching/learning process and associated activities significantly helped students to form long-term memories. A future study investigating the impact of RLS sessions during basic science training period on facilitating students learning and understanding of neurology/related subjects in their clinical years would be ideal to further confirm the current results.

Due to technical reasons, we could not obtain responses on learning perception from students who attended traditional sessions and this is one of the limitations of the study. Also due to practical issues, we conducted this study in three groups. Therefore, some variations in the learning ability of various groups of students could have influenced the outcome measures and this could be the other limitation of the study. However, we believe that this effect may be negligible, as the admission criteria for all three groups of students were the same for the Bachelor of Medicine and Bachelor of Surgery in our medical school.

Conclusions

Traditional didactic teaching sessions blended with RLS created a positive influence on student learning compared to didactic lecturing alone. Students were able to understand various scenario demonstrations conducted in the class as demonstrated by their better performance in the assessments. RLS sessions blended with multiple assignments, peer discussions, multiple formative assignments, and facilitator feedback sessions further enhanced student learning. These students scored higher in the summative tests compared to students who were exposed to RLS sessions blended with assignments or students who were exposed to traditional didactic lecturing alone. Students acknowledged RLS sessions well, as the sessions created a positive teaching and learning environment that facilitated relating of concepts taught in the class with everyday life. As a result, CNS learning becomes relevant and meaningful.

Declarations

The authors declare no conflict of interest. The students who appear in the representative images have voluntarily agreed to participate in the same.

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Figure legends

Figure 1. A flow-chart depicting the scheme of the study.

Figure 2. Representative photograph of students participating in a demonstration of touch sensation in which, the student volunteer is instructed to stand facing the class with eyes closed and with a wisp of cotton, the facilitator touched his skin over the palm's dorsum (A), demonstration of lateral inhibition in which three volunteers in the picture represents three sensory units. Whenever the middle sensory unit (student in the middle) is activated, she will touch the students standing laterally (other sensory units) to inhibit action potential transmitting on them (B), and diagrammatic representation of neural circuitry for lateral inhibition process (C).

Figure 3. Representative photograph of students participating in a demonstration of knee jerk wherein the patellar tendon of the student volunteer is tapped using a knee hammer (A), and withdrawal reflex act stages; where, a student volunteer is receiving a noxious stimulus (B) and withdrawal of the hand from the source of the noxious stimulus (C).

Figure 4. Representative photograph of a student participating in a demonstration of fine skilled voluntary activity such as writing the name of the student volunteer on the board (A, B, and C).

Figure 5. Representative photograph of students participating in a demonstration of motor coordination, the finger-nose test where a student volunteer touches the facilitator’s finger (A), then touches her nose and it was repeated in rapid succession (B) and rapid alternating movements, quick pronation and supination of the hand (C).

Figure 6. Representative photograph of students participating in the demonstration of initiation of voluntary motor activity- in which a student volunteer sits on a chair placed in front of the

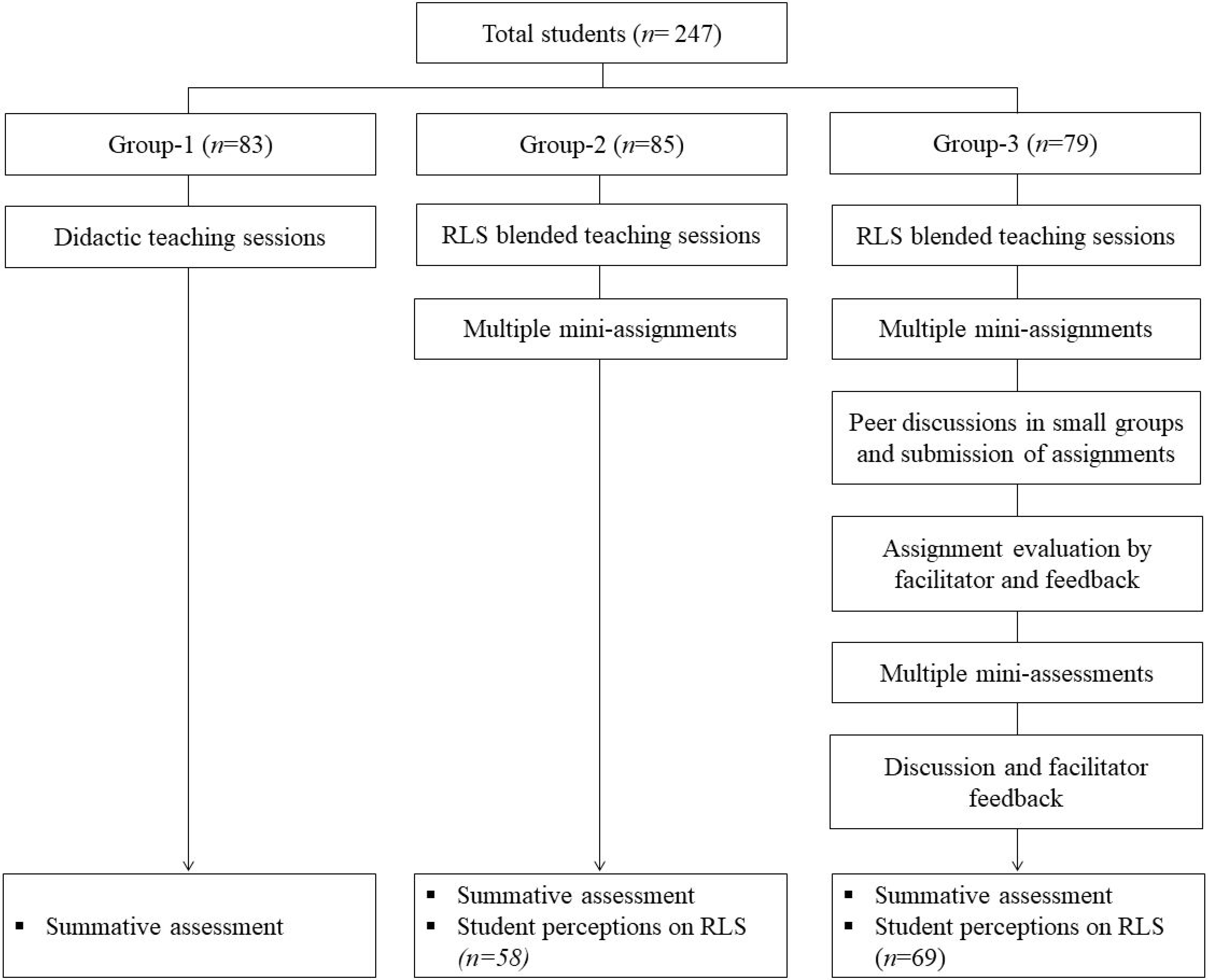
class (A) and then is instructed to get up quickly (B), scaling of motor activity- in which students write English alphabet letter ‘a’ on the notebook (C), while one representative of the class writing the same letter on the board and their size comparison (D), scaling and timing of motor activity with a real-life demonstration in which a student is asked to catch a small ball, his hands are subconsciously manipulated accordingly to accommodate that small ball (E) but when the ball's size increases, a change is also brought about subconsciously in the hands (F). In addition, during timing of motor activity, when a ball is approaching quickly on anyone the response of that individual will be faster compared to when it is approaching slowly irrespective of the ball size (E and F).

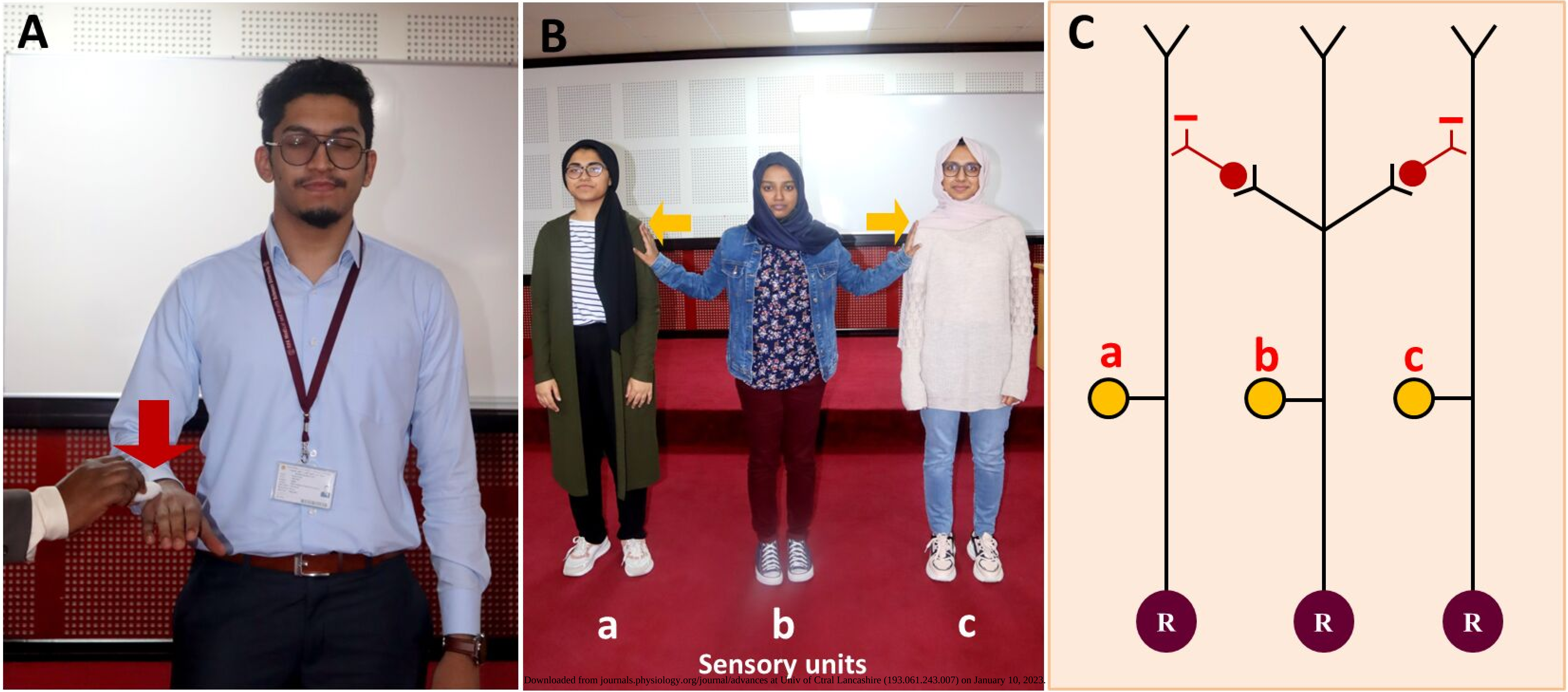
Figure 7. Diagrammatic representation of the sequence of impulse flow in the brain when a person speaks a written word (A), a representative photograph of a student participating in a demonstration of speaking a written word such as ‘Chair’ (B), a diagrammatic representation of the sequence of impulse flow in the brain when a person speaks a heard word (C).

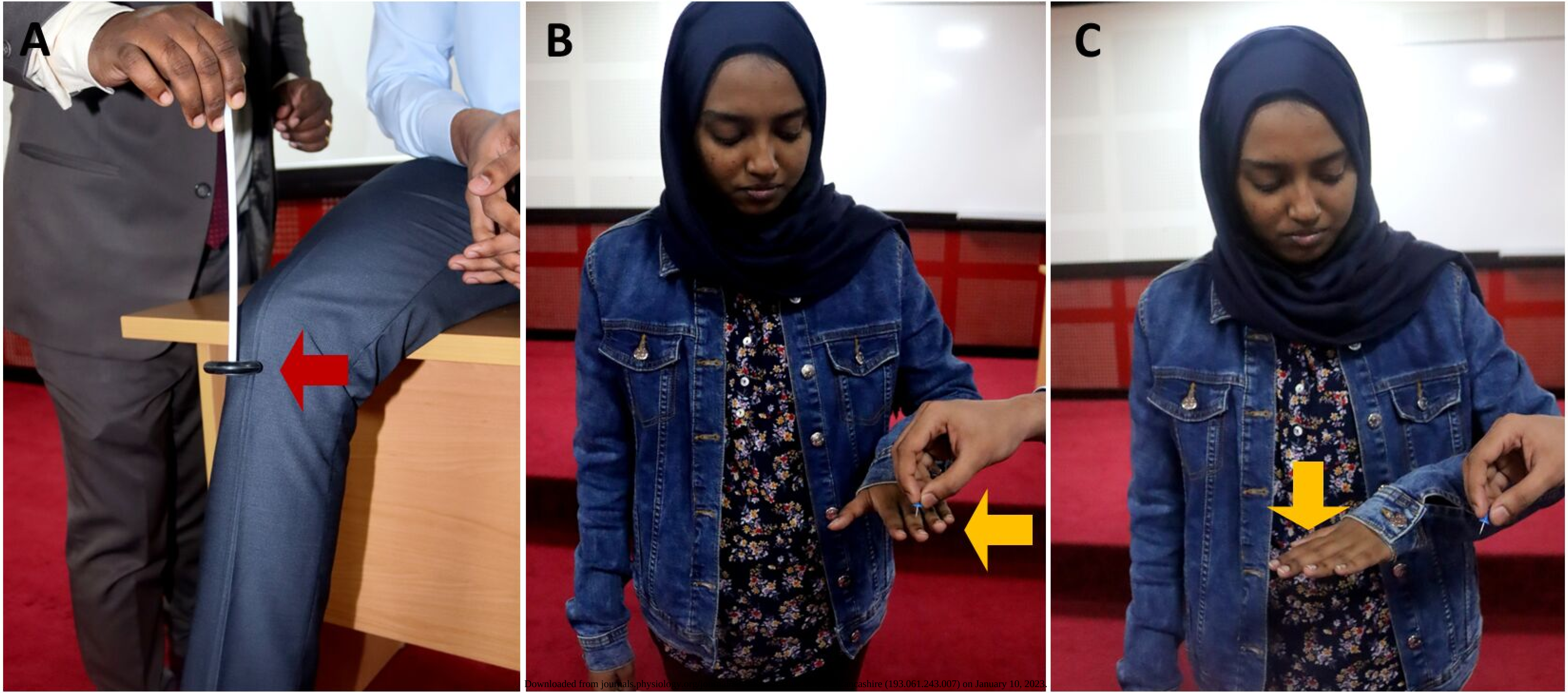
Figure 8. Comparison of physiology scores of various groups in the continuous assessment (A) where Group-3 students scored significantly higher compared to the other groups, and final summative examinations (B) where, also Group-3 students who experienced RLS sessions blended with multiple assignments, peer discussions, multiple formative assignments, and facilitator feedback sessions have scored higher than the others. ***$p>0.0001$

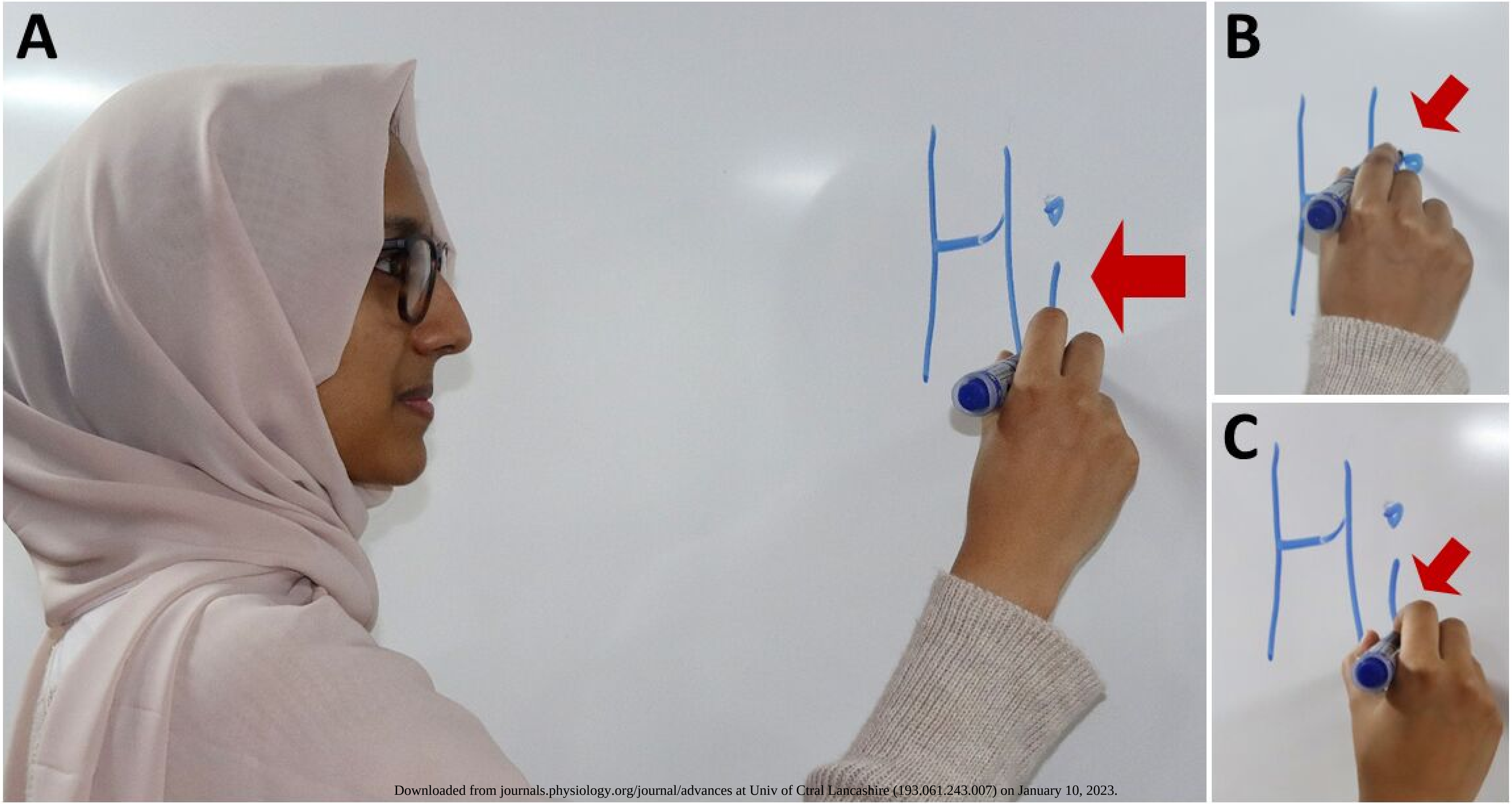
Figure 9. Graphical representation of Group-2 student satisfaction regarding RLS blended teaching sessions. Please note; CLS- Questions on collaborative learning skills and RS- Questions on researching skills.

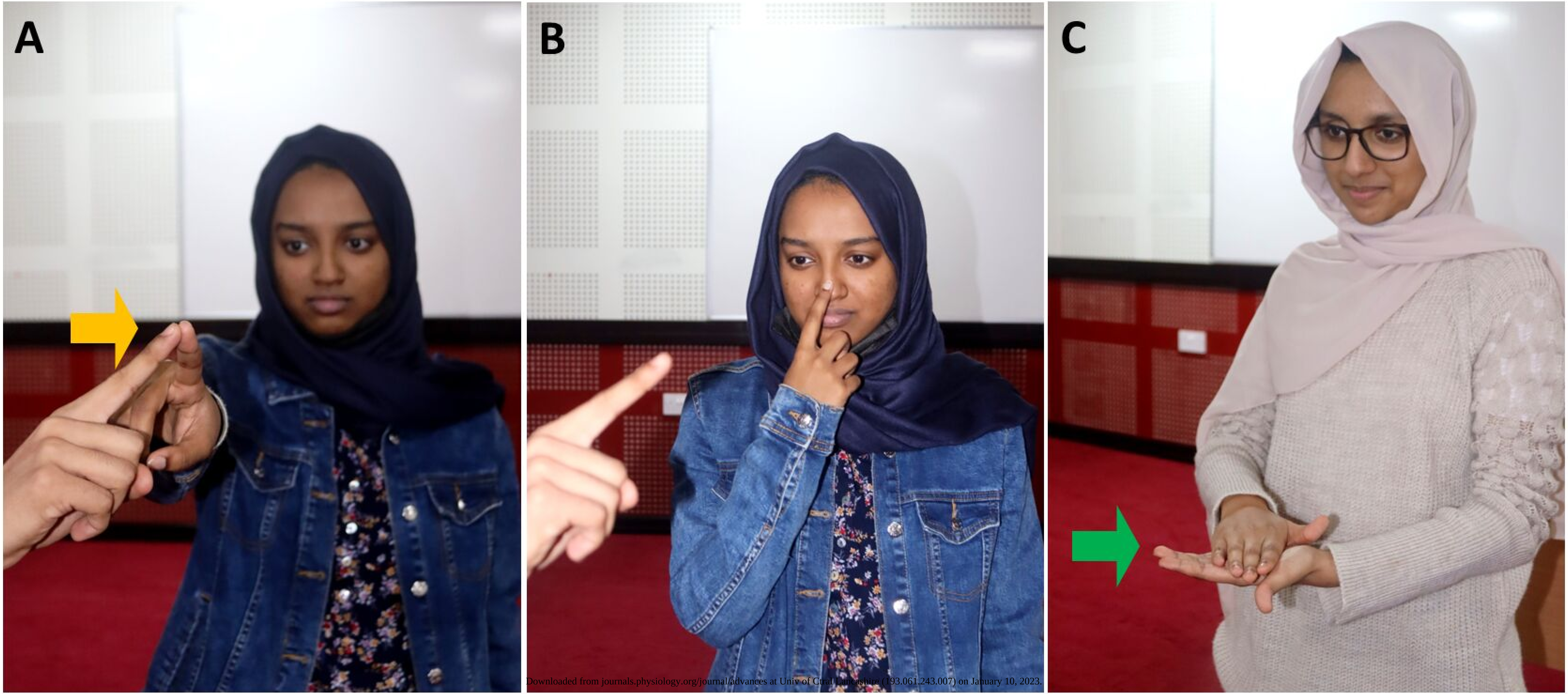
Figure 10. Graphical representation of Group-3 student satisfaction regarding RLS blended teaching sessions. Please note; CLS- Questions on collaborative learning skills and RS- Questions on researching skills.

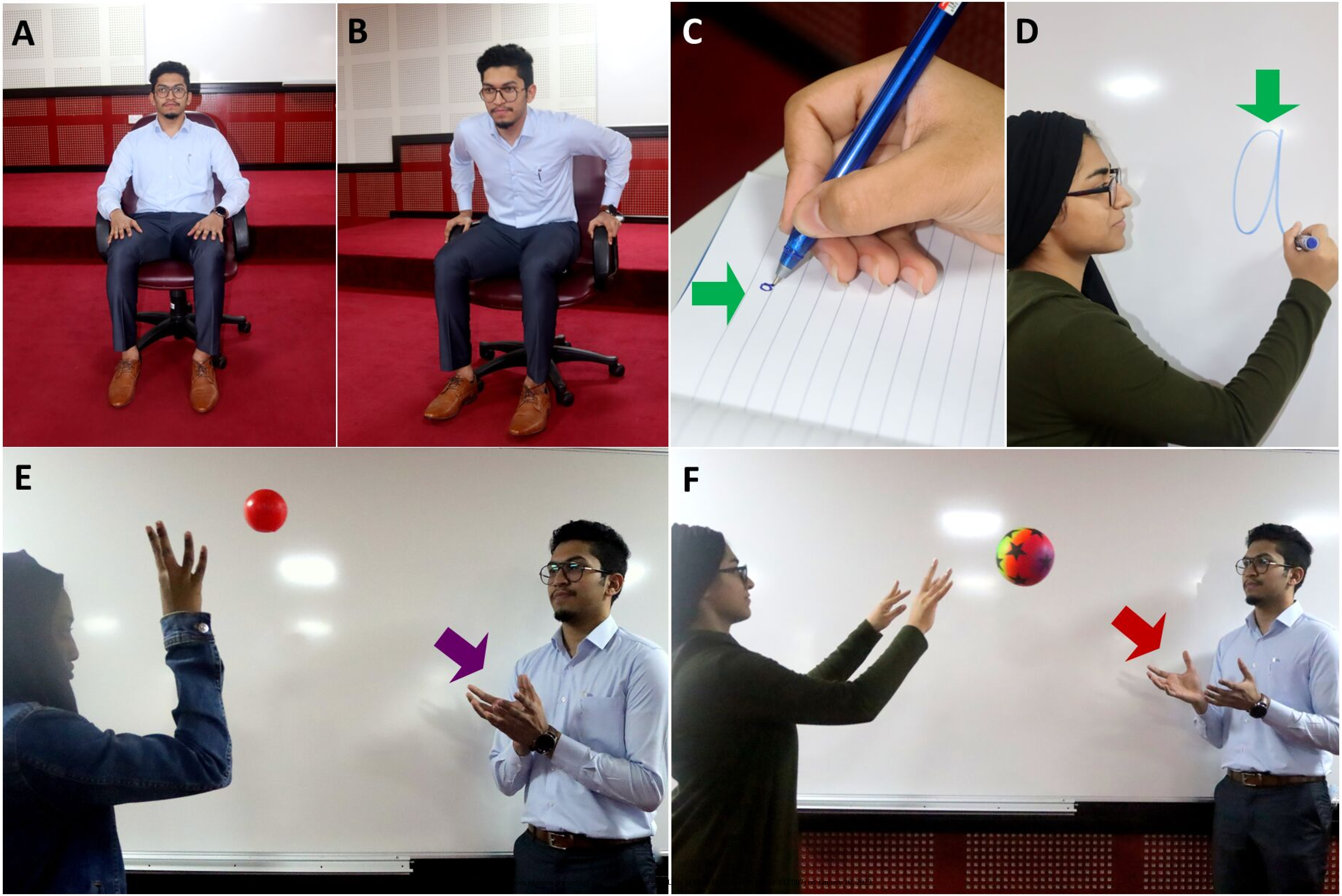

Total students (n= 247)
Group-1 (n=83)
Group-2 (n=85)
Group-3 (n=79)
Didactic teaching sessions
RLS blended teaching sessions
RLS blended teaching sessions
Multiple mini-assignments
Multiple mini-assignments
Peer discussions in small groups and submission of assignments
Assignment evaluation by facilitator and feedback
Multiple mini-assessments
Discussion and facilitator feedback
Summative assessment
Summative assessment
Student perceptions on RLS (n=58)
Summative assessment
Student perceptions on RLS (n=69)

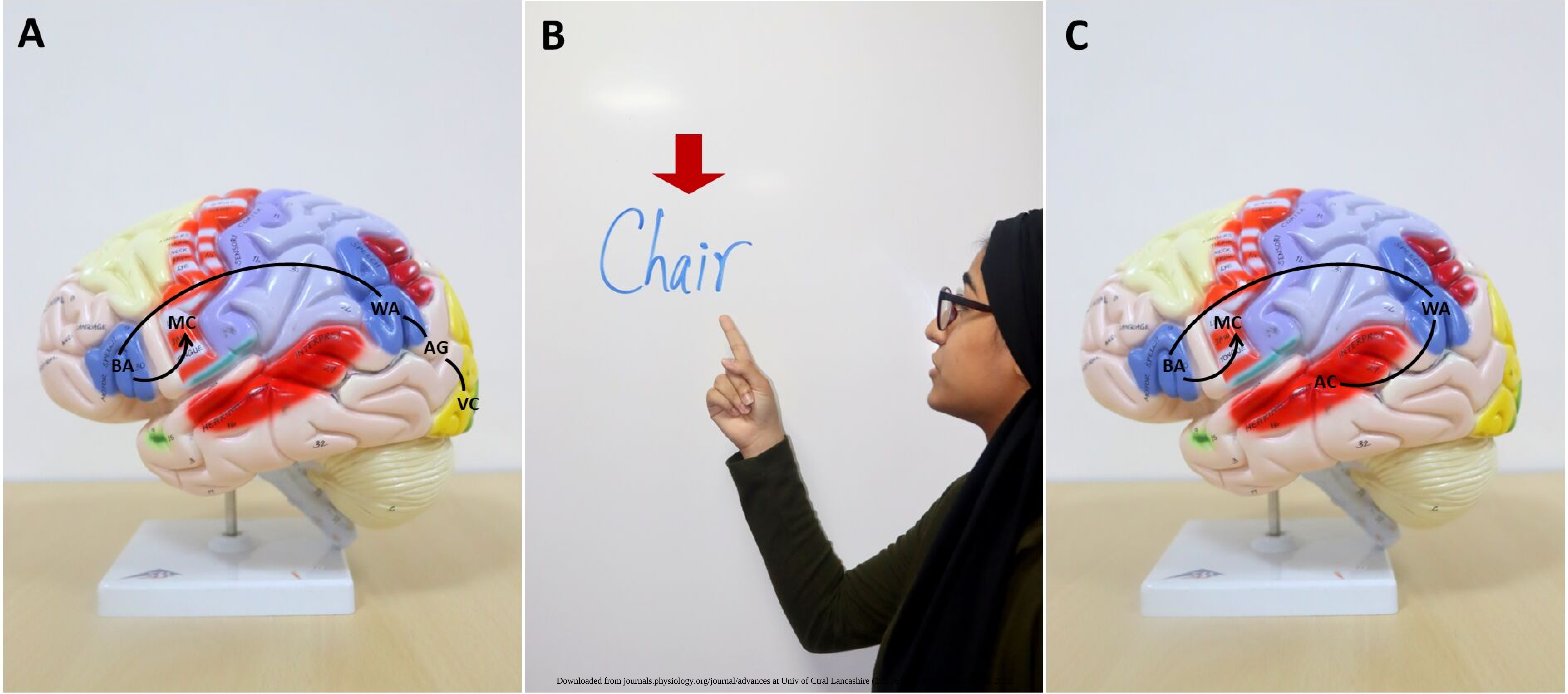

A
B
a
b
c
Sensory units
C
a
b
c
R
R
R

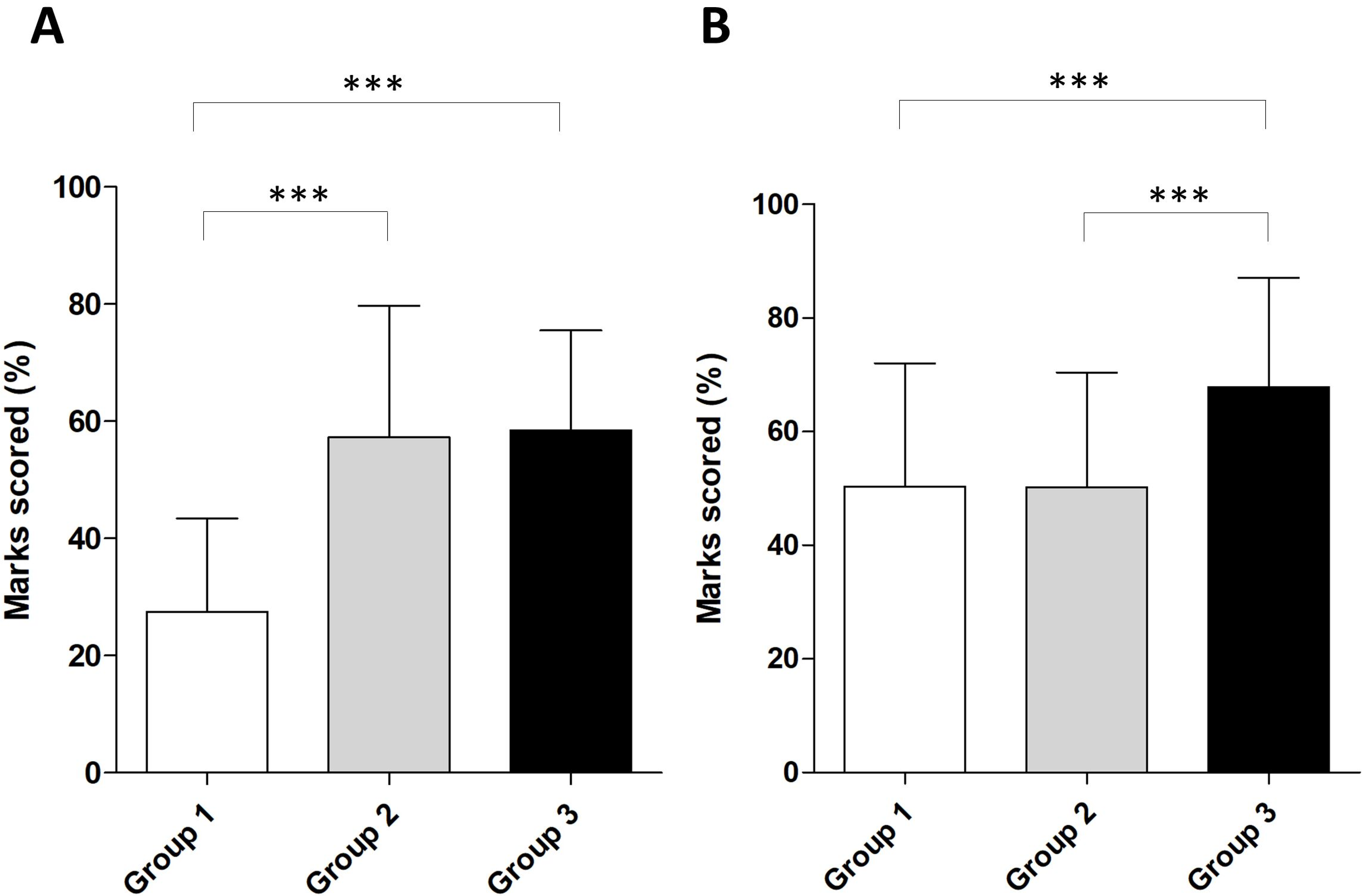

A
B
C

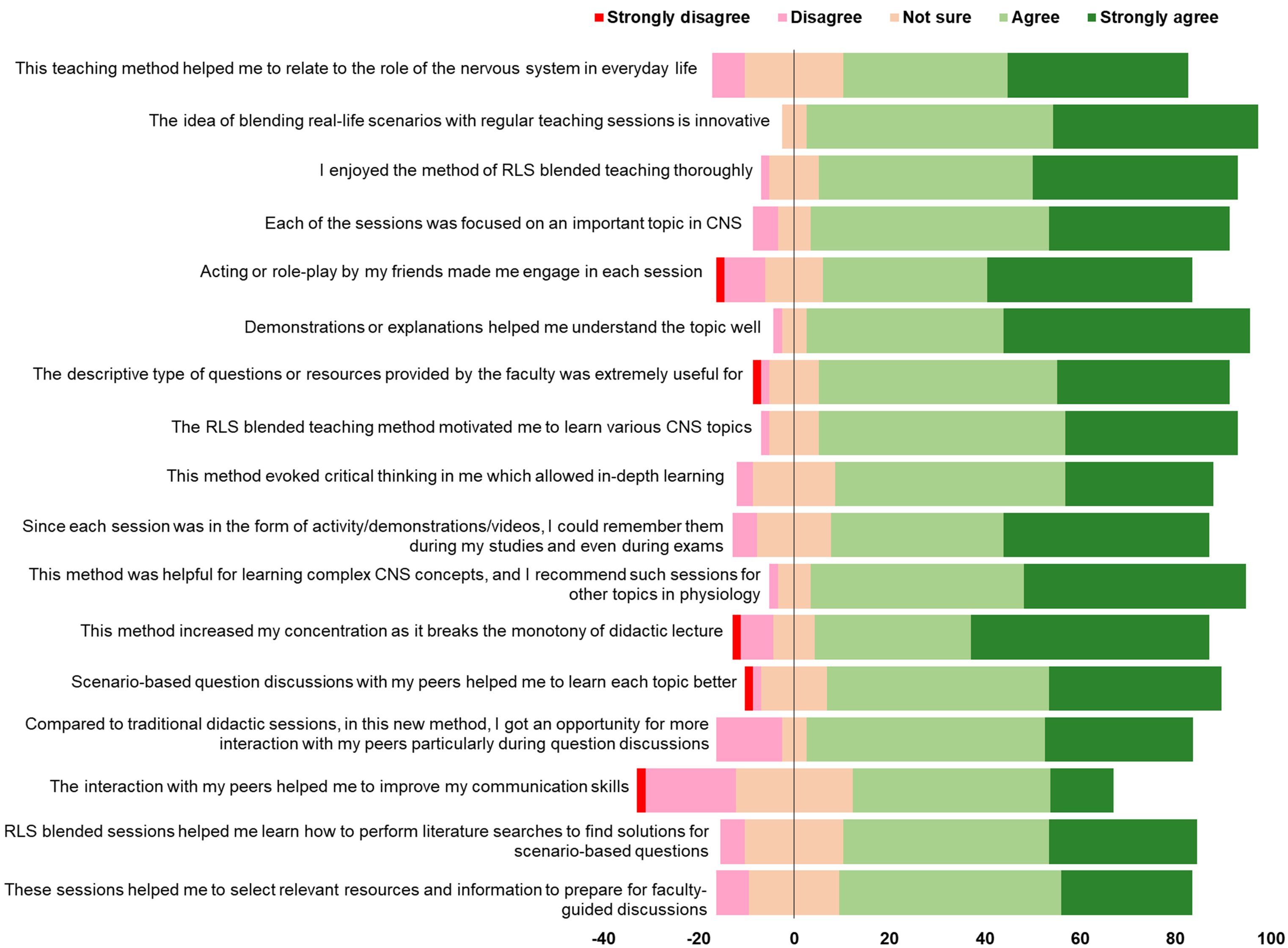

A
B
C


A
B
C


A
B
C
D
E
F


A
BA
MC
WA
AG
VC
B
Chair
C
BA
MC
WA
AC


A
B
***
***
***
***
Marks scored (%)
100
80
60
40
20
0
Group 1
Group 2
Group 3



Strongly disagree
Disagree
Not sure
Agree
Strongly agree
This teaching method helped me to relate to the role of the nervous system in everyday life
The idea of blending real-life scenarios with regular teaching sessions is innovative
I enjoyed the method of RLS blended teaching thoroughly
Each of the sessions was focused on an important topic in CNS
Acting or role-play by my friends made me engage in each session
Demonstrations or explanations helped me understand the topic well
The descriptive type of questions or resources provided by the faculty was extremely useful for
The RLS blended teaching method motivated me to learn various CNS topics
This method evoked critical thinking in me which allowed in-depth learning
Since each session was in the form of activity/demonstrations/videos, I could remember them during my studies and even during exams
This method was helpful for learning complex CNS concepts, and I recommend such sessions for other topics in physiology
This method increased my concentration as it breaks the monotony of didactic lecture
Scenario-based question discussions with my peers helped me to learn each topic better
Compared to traditional didactic sessions, in this new method, I got an opportunity for more interaction with my peers particularly during question discussions
The interaction with my peers helped me to improve my communication skills
RLS blended sessions helped me learn how to perform literature searches to find solutions for scenario-based questions
These sessions helped me to select relevant resources and information to prepare for faculty-guided discussions
-40
-20
0
20
40
60
80
100

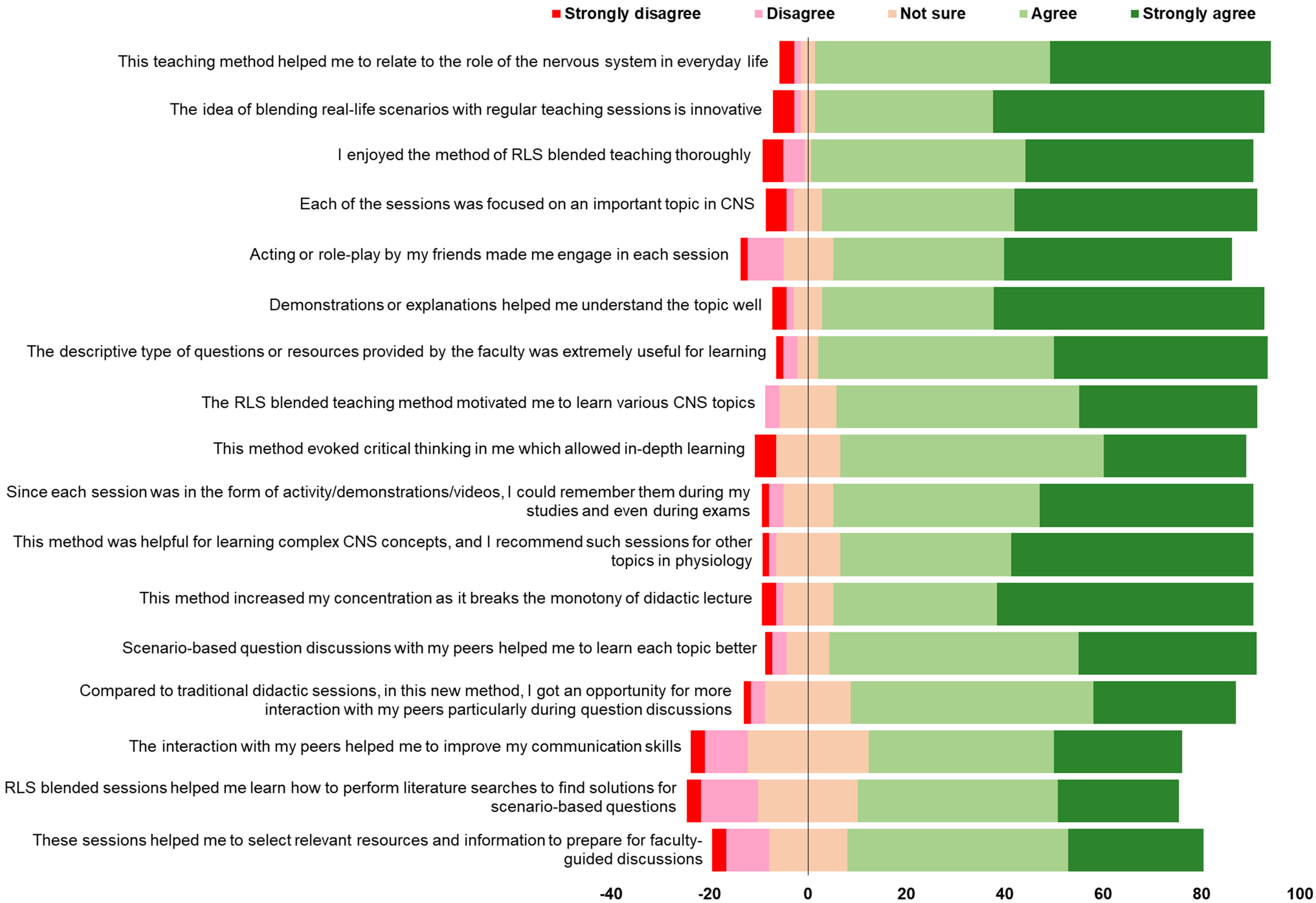

Strongly disagree
Disagree
Not sure
Agree
Strongly agree
This teaching method helped me to relate to the role of the nervous system in everyday life
The idea of blending real-life scenarios with regular teaching sessions is innovative
I enjoyed the method of RLS blended teaching thoroughly
Each of the sessions was focused on an important topic in CNS
Acting or role-play by my friends made me engage in each session
Demonstrations or explanations helped me understand the topic well
The descriptive type of questions or resources provided by the faculty was extremely useful for learning
The RLS blended teaching method motivated me to learn various CNS topics
This method evoked critical thinking in me which allowed in-depth learning
Since each session was in the form of activity/demonstrations/videos, I could remember them during my studies and even during exams
This method was helpful for learning complex CNS concepts, and I recommend such sessions for other topics in physiology
This method increased my concentration as it breaks the monotony of didactic lecture
Scenario-based question discussions with my peers helped me to learn each topic better
Compared to traditional didactic sessions, in this new method, I got an opportunity for more interaction with my peers particularly during question discussions
The interaction with my peers helped me to improve my communication skills
RLS blended sessions helped me learn how to perform literature searches to find solutions for scenario-based questions
These sessions helped me to select relevant resources and information to prepare for faculty-guided discussions
-40
-20
0
20
40
60
80
100

Table- 1. Representative real-life scenario assignments provided to group 2 and 3 students

1. Tactile sensation (Touch sensation)

During a Physiology theory teaching session, the faculty requested one of the student volunteers to come on to the dais to demonstrate light touch to the whole class as a lid opener to the sensory pathways. The faculty used a wisp of cotton and stimulated the dorsal surface of the right hand with the subject's eyes closed and asked the volunteers to answer several questions about that sensation. In response to the faculty's question on where exactly the stimulus was applied, the volunteer precisely showed the area stimulated with the other hand.

A. Which pathway carries the above sensation? Trace the pathway that carries this sensation.
B. With the help of a diagram depicts the area in the brain in which this sensation is integrated and processed.
C. What is the physiological basis for the student's precise localization of the area stimulated?

2. Reflex

In a physiology practical teaching session, the facilitator demonstrated a deep reflex by tapping the patellar tendon on a student volunteer. The tapping gives rise to a sudden extension of the student's leg. The fellow students were amazed at seeing the sudden response of the student's leg following a sharp hit on the patellar tendon.

A. Why does tapping the tendon result in such a response in the leg in the above scenario?
B. At which spinal cord level is this reflex integrated?
C. Name the receptor for this reflex and describe the nerve supply to it.
D. What happens to the above reflex in an upper motor neuron type of lesion? Justify your answer.

3. Higher brain functions

As a part of the reaction time experiment, Ms. 'M' requested a volunteer to repeat the word that she said to him. She said the word 'chair' and asked him to repeat it. Within a short while, he responded by saying the word 'Chair'.

A. Which brain region is responsible for the language comprehension in him?
B. Where is the location of this brain region that is involved in language comprehension?
C. What is the connection between handedness and this brain region involved in language comprehension in humans?
D. Write the entire neural pathway by which he responded to Ms. M's command.
E. Damage to the above language comprehension region leads to what type of language abnormality?

Table-2. Group-2, student perceptions on specific methods used for RLS blended teaching session

SI No.	Questions	Strongly Agree	Agree	Not sure	Disagree	Strongly disagree
Satisfaction regarding specific methods used for RLS blended teaching sessions						
Tactile sensation (Touch sensation)						
1	The method adopted to present this situation was clear, and I understood it well.	*28 (48.27)*	*25 (43.10)*	*4 (6.89)*	-	*1 (1.72)*
Reflex (Withdrawal reflex)						
2	The student involved demonstration method for presenting this session was very apt and clear.	*26 (44.82)*	*30 (51.72)*	*2 (3.44)*	-	-
Fine voluntary activity						
3	The method used to demonstrate this situation was clear and focused on the topic.	*27 (46.55)*	*28 (48.27)*	*3 (5.17)*	-	-
Initiation, timing, and scaling the movements						
4	I enjoyed the role-play/demonstrations aimed at presenting all of these situations, and all of them were very clear.	*27 (46.55)*	*28 (48.27)*	*2 (3.44)*	*1 (1.72)*	-
Motor coordination						
5	The faculty role-play and demonstrations adopted to depict this scenario were very precise and very clear.	*27 (46.55)*	*23 (39.65)*	*7 (12.06)*	*1 (1.72)*	-
Emotion						
6	Video presented during this session was apt for discussing the physiology of emotion.	*19 (32.75)*	*27 (46.55)*	*9 (15.51)*	*2 (3.44)*	*1 (1.72)*
Speaking heard and written word						
7	The student and faculty involved demonstrations used to depict this scenario were very useful in learning.	*26 (44.82)*	*27 (46.55)*	*4 (6.89)*	-	*1 (1.72)*
Learning and memory						
8	Student demonstrations and short memory test/games presented to illustrate this scenario were ideal for learning.	*28 (48.27)*	*23 (39.65)*	*6 (10.34)*	*1 (1.72)*	-
Reasoning and working memory						
9	The interview session presented to depict reasoning and working memory was innovative and clear.	*27 (46.55)*	*25 (43.10)*	*5 (8.62)*	*1 (1.72)*	-

Note: n=58, Percentage is represented in brackets

Table-3. Group-3, student perceptions on specific methods used for RLS blended teaching session.

SI No.	Questions	Strongly Agree	Agree	Not sure	Disagree	Strongly disagree
Satisfaction regarding specific methods used for RLS blended teaching sessions						
Tactile sensation (Touch sensation)						
1	The method adopted to present this situation was clear, and I understood it well.	*37 (53.6)*	*31 (44.9)*	*1 (1.4)*	-	-
Reflex (Withdrawal reflex)						
2	The student involved demonstration method for presenting this session was very apt and clear.	*41 (59.4)*	*22 (31.9)*	*2 (2.9)*	*2 (2.9)*	*2 (2.9)*
Fine voluntary activity						
3	The method used to demonstrate this situation was clear and focused on the topic.	*39 (56.5)*	*26 (37.7)*	*3 (4.3)*	-	*1 (1.4)*
Initiation, timing, and scaling the movements						
4	I enjoyed the role-play/demonstrations aimed at presenting all of these situations, and all of them were very clear.	*40 (58)*	*24 (34.8)*	*2 (2.9)*	*1 (1.4)*	*2 (2.9)*
Motor coordination						
5	Faculty role-play and demonstrations adopted to depict this scenario were very precise and very clear.	*38 (55.1)*	*26 (37.7)*	*2 (2.9)*	*3 (4.3)*	-
Emotion						
6	The video presented during this session was apt for discussing the physiology of emotion.	*27 (39.1)*	*28 (40.6)*	*13 (18.8)*	-	*1 (1.4)*
Speaking heard and written words						
7	The student and faculty involved demonstrations used to depict this scenario were very useful for learning.	*38 (55.1)*	*28 (40.6)*	*2 (2.9)*	-	*1 (1.4)*
Learning and memory						
8	Student demonstrations and short memory test/games presented to illustrate this scenario were ideal for learning.	*34 (49.3)*	*32 (46.4)*	*2 (2.9)*	-	*1 (1.4)*
Reasoning and working memory						
9	The interview session presented to depict reasoning and working memory was innovative and clear.	*32 (46.4)*	*31 (44.9)*	*3 (4.3)*	*2 (2.9)*	*1 (1.4)*

Questions related to RLS practice question assignments, submission and evaluation/feedback						
10	RLS assignment exercise and feedback sessions helped me read various physiology concepts repeatedly, which facilitated my learning.	*24 (35.3)*	*34 (50)*	*8 (11.8)*	*2 (2.9)*	-
Questions related to practice (mock) exams						
11	Mock tests conducted before the actual module examination were truly beneficial, motivated me to learn, and helped assess and reflect on my level of learning and understanding of various concepts. (*n*=61)	*38 (62.3)*	*18 (29.5)*	*3 (4.9)*	*2 (3.3)*	-
Questions related to module exams						
12	RLS had a significant role in my mid-module examination performance as it helped me easily recall various learnt aspects while answering various physiology questions.	*26 (37.7)*	*31 (44.9)*	*9 (13)*	*2 (2.9*	*1 (1.4)*
13	RLS had a significant role in my performance in the end module examination as it helped me easily recall various learnt aspects while answering various physiology questions.	*24 (34.8)*	*33 (47.8)*	*9 (13)*	*1 (1.4)*	*2 (2.9)*
Questions related to end year exams						
14	RLS sessions had a positive impact on my end year module examination physiology questions as it helped me easily recollect various learnt aspects while answering related physiology questions.	*22 (31.9)*	*34 (49.3)*	*7 (10.1)*	*7 (10.1)*	*4 (5.8)*

Note: n=69, Percentage is represented in brackets

Table 4. *Themes, their definitions, and group-3 student's quotes on the RLS method*

Theme	Definition	Student quotes
Innovative initiative	This theme portrays that the students value the RLS method as a novel approach in inquisitiveness evoked learning	"This method was extremely innovative"
Enjoyable experience	This theme indicates the effectiveness of the RLS method in making the learning enjoyable, easier and fun	"It made learning physiology in this module easier and fun" "The focus on theoretical clinical scenarios made the concepts a lot more enjoyable"
Mental grasp	The RLS method significantly facilitated students to comprehend fundamental concepts in neuroscience	"RLS learning helped me a lot to improve my understanding about the subject" "The demonstrations we had in class with our peers really helped in understanding and remembering the concepts"
Effective engagement	This theme demonstrates that the RLS method was interesting and interactive which enhanced the engagement of students in the classroom	"Really enjoyed every physiology class since it was very interactive and engaging" "I was attentive through every part of the lecture"
Intrinsic motivation	It defines that the RLS method encouraged students to study well for the challenge entailed for their inherent satisfaction in contrast to external pressures or rewards	"Focusing on theoretical medical scenarios was very helpful and motivated me to study better" "It encouraged me to study in order to be able to answer the questions and the feedback from the doctor was helpful"
Experience retrieval	Define that the RLS method eased the process of recovering information of classroom learning events by mental effort	"I even added the names of the student and a brief description of what they did in the class to my PowerPoint and that really helped me while studying" "Helped in allowing the class act replay in the mind and easily remember what the concept was"
Helpful approach	Defines that the RLS method was helpful in learning, remembering, and recollection of concepts in assessments	"RLS blended learning was generally more helpful than the usual teachings methods" "RLS learning helped me a lot to improve my understanding about the subject and it was very helpful, especially for the exams"
Strong positive feeling	This defines that RLS sessions supported students in diverse ways and that persuaded a very strong positive feeling of wanting more RLS sessions among them	"Wish this was done more for other subjects and from the beginning of 1st year" "I learned a lot, thanks to the RLS blended teaching" "Would want to attend such classes more in the future"
Appreciativeness	Since the RLS method positively influenced students learning, it induced a warm positive feeling of gratefulness towards the teaching faculty	"Thank you for letting us experience this" "Thank you doctor for making these physiology sessions so interesting" "The sessions were very interesting. Thank you"