Short-term research projects in cognitive neuroscience for undergraduate students: a contingency plan to maintain quality teaching during COVID-19 pandemic

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Abstract

The Corona Virus Disease 19 (COVID-19) pandemic has imposed serious restrictions for academic institutions to maintain their research and teaching practical subjects. Universities have implemented adaptive measures to maintain educational activities and achieve the learning objectives for undergraduate and postgraduate students by shifting to online teaching and learning. Although such approaches have enabled delivering the theoretical content of courses during the pandemic, universities have faced serious difficulties in running practicals with actual research experiments and teaching hand-on skills because such activities potentially override the required safety guidelines. Here, we report an adaptive measure, implemented at Monash University, to run home-based studies in cognitive neuroscience and achieve learning objectives, which are normally delivered in face-to-face practicals. We introduce two specifically designed short-term research projects and describe how different aspects of these projects, such as tutorials, experiments, and assessments, were modified to meet the required social distancing. The results of cognitive tests were closely comparable between the laboratory-based and home-based experiments indicating that students followed the guidelines and the required procedures for a reliable data collection. Our assessments of students’ performance and feedback indicate that the majority of our educational goals were achieved, while all safety guidelines and distancing requirements were also met.

INTRODUCTION

The ongoing Corona Virus Disease 19 (COVID-19) pandemic has imposed serious restrictions for traveling and group activities from early March 2020 and consequently affected on-campus research and educational activities in Australia for the undergraduate and postgraduate courses and higher degree by research students. During pandemics, universities have several key responsibilities: 1) ensuring the safety of the students, academic and professional staff by applying suitable social isolation and distancing and infection control measures (1); 2) minimizing disruptions to the curriculum by implementing essential changes in delivery of teaching and learning in both educational and research activities; and 3) embracing novel approaches for active and distance learning to advance neuroscience education for the forthcoming years. Accordingly, academic institutions have implemented adaptive measures to maintain education and research activities (2). Figure 1 is a summary of the steps in our adaptive approach for developing active and distance learning in neuroscience education.

The steps highlighted in the Fig. 1 could be used as a guideline for development of a flexible active- and distance-learning approaches in neuroscience education.

SHORT-TERM RESEARCH PROJECTS FOR UNDERGRADUATE STUDENTS

Since 2017, the Short-Term Research Project (SRP) has been introduced into a third-year neuroscience course (Cognitive and Sensory Neuroscience: Code PHY3111) in the Physiology Department at Monash University. These projects are the practical laboratory components and contribute 25% to the total mark in this neuroscience course. These projects are designed by experienced research-active academics and also aligned well with the theoretical content of the course. The project and the related data collections are completed across 11 weeks within a semester. In the first
week of the semester, students are informed about each project’s topic and requirements and then voluntarily enroll in one of these projects through the dedicated course management online system (Moodle). Students participate in each project as participants (individuals who take part in research) and also as investigators (collect, analyze, and interpret the data and also tabulate and present the results). The current article mainly focuses on two projects in cognitive neuroscience (Table 1).

These projects were carefully designed to be appealing for students and address some of their daily life experiences. In project one, the main focus was on postural balance and studied the effects of cognitive load on the postural balance. Many cases of balance loss and falls and the resulting injuries occur in elderly and people intoxicated with alcohol when they perform multiple tasks simultaneously (3). Students investigated how cognitive load affected postural balance. Previous studies have shown that Stroop test is a demanding task that requires selective attention and executive control to resolve the conflict between behavioral options and therefore this test was used to increase the cognitive load and examine its effects on participants’ balance (4–6). Furthermore, recent studies indicate the role of “attention” in modulation of postural balance control when concurrent control of balance and performance in cognitive tasks are required (7–9). Accumulating evidence indicates a trade-off between the balance regulation and cognitive control as simultaneous requirements for both tasks become too challenging (7–9).

In project 2, the main aim was investigating the effects of music on cognitive control (6, 10) in healthy young adults. This topic was appealing for many students because music is one of the most frequently encountered contextual factors. Students listen to music during driving, exercise and even studying. Recent studies indicate that background music significantly influences cognitive functions in cognitive tasks.

### Table 1. Cognitive neuroscience projects offered for undergraduate students

| Project 1: how increased cognitive load affects postural balance in healthy young adults |
|---|
| **Aim:** to investigate the effects of increased cognitive load on postural balance in healthy young adults |
| **Study design:** pre-post crossover design |
| **Cognitive task:** computerised version of the Stroop task (30 min) |
| **Outcome measures:** indexes of postural sway during static and dynamic tasks (NeuroCom Basic Balance Master); behavioral measures such as percentage of errors and response time |

| Project 2: how different types of music affect cognitive control in healthy young adults |
|---|
| **Aim:** to investigate the effects of different types of music on executive control of goal-directed behavior |
| **Study design:** repeated-measure design testing the effects of various background acoustic conditions (music, white noise, and silence) on participants’ performance in two cognitive tasks |
| **Cognitive tasks:** computerised version of the Wisconsin Card Sorting Test (WCST) and Stroop test |
| **Outcome measure:** reaction time (RT) and error rate (ER) |
such as the Wisconsin Card Sorting Test (WCST) and Stroop test. These effects of music appear as changes in the percentage of errors and participants’ response time but the direction of change depends on the music tempo and differs between males and females (11–13). These findings have prompted additional studies to reveal the effects of music on cognitive functions (12). These relevant studies were discussed with students as the theoretical framework of their projects.

Research Topics for Students

Each student group was supposed to select one of the following topics for their literature review and poster presentation and discuss the results of their experiments in the context of their selected topic:

**Project 1.**

*Project 1* investigated the following: effects of cognitive load on balance in elderly and contextual factors, such as concurrent task performance on balance.

**Project 2.**

*Project 2* investigated the beneficial effects of music on cognitive functions and rehabilitation approaches in the following: schizophrenia, mood disorders, anxiety disorders, and drug addiction.

Cognitive Tasks

**WCST.**

The WCST is a routine clinical test of cognitive flexibility that demands participation and coordination of multiple cognitive functions such as implementing and shifting between behavior-guiding rules, working memory of rule, and selective attention (5, 6). We used a computerized version of the WCST (14–16) in which all items were shown on a monitor screen and responses were made by moving a computer mouse and clicking on each item. Participants had to match a sample item with one of the four test items based on color, shape, or the number of symbols on each item. The symbols on the sample item matched one of the test items in “color,” matched another test item in “shape,” and the other test item in the “number” of symbols; however, the remaining (fourth) test item did not match by any rule. The relevant rule for matching (color, shape, or number) was not cued and changed without notice when participants’ performance reached a criterion of 9 corrects out of 10 consecutive trials. Participants had to find the relevant rule by trial and error. After starting the WCST, they had to complete 100 trials. The number of rule shifts, percentage of correct responses, and response time for each rule were recorded.

**Stroop test.**

The Stroop test is also a routine clinical test to assess selective attention and inhibition ability (4, 5, 17, 18). In each trial of the Stroop test, a color name (e.g., red, green, blue) appeared in different font colors at the center of the screen. Participants were instructed to ignore the color name and respond to the font color and press the related button on the computer keyboard (e.g., “r” for red, “g” for green, “b” for blue, ...). In congruent trials, the name and font color of the word matched (word green printed in green font), but in incongruent trials they did not match (word green printed in red font). Participants’ response time and percentage of correct responses were recorded. At the end of the session, participants had to copy their data into tabulated tables in an Excel file (prepared and provided by the project leaders). At the conclusion of experiments, students had to conduct some preliminary analysis on the tabulated data and send them directly to the project leader for further class wise analyses.

Rational behind the Use of SRPs in Undergraduate Neuroscience Courses

SRPs are mainly laboratory-based with complementary theoretical lectures and therefore play crucial roles in achieving various learning objectives in neuroscience courses (19, 20). These projects include all research activities from data collection to analysis of these data and finally presentation of the findings to help students gain practical experience and understand important concepts that cannot be easily conveyed through theoretical lectures or textbooks. These concepts are as follows:

- The variability and limitations inherent in biological and behavioral measurements.
- The advantages and disadvantages of various neurobiological techniques for studying the brain functions.
- The necessity for controlling confounding factors. Students learn to consider and control various nonspecific factors that may influence the outcome of biological and behavioral assessments.
- The importance of unbiased data collection and tabulation and choosing reliable analytical approaches to evaluate and interpret results.
- The proper application of statistical analyses on actual data, collected by students, to appreciate the significance of statistical inference.
- The importance of working in groups. Practical laboratories also aim at encouraging and fostering group work for the preparation and presentation of a scientific report (written or oral presentation) and preparing students for future responsibilities that would involve collaborative work.

COVID-19 Pandemic and the Problem of Running SRPs in Cognitive Neuroscience

Even though the online teaching and learning are reasonable responses to deliver theoretical content of courses during COVID-19 pandemic, running short-term research projects (SRPs) for undergraduate students, which involve the process of handling of participants and collection of research data from humans or animal models within the practical laboratories, became almost impossible. That is mainly because this contradicts the quarantine and distancing requirements and safety guidelines during the pandemic (refer to *step 1* in Fig. 1).

Contingency Plans during COVID-19 Pandemic

While works by authorities are ongoing to contain the virus spread, the authors of this manuscript believe that this is an appropriate time to examine and reflect on the impact...
that medical crises like COVID-19 can have on teaching and learning of undergraduate Science and Biomedical students and to evaluate the "contingency plans" to ensure quality undergraduate education even in the face of continuous interruptions in the face-to-face activities due to COVID-19 pandemic. Identification of the curricular needs, modification of active learning tasks, and training of the staff during COVID-19 pandemic were the essential steps (refer to steps 2 and 3 in Fig. 1) to achieve this goal.

**AIMS**

The main aim of this paper is to show that despite COVID-19 outbreak and its imposed restriction on various activities in Universities, adaptive measures enabled running SRPs for undergraduate Science and Biomedical students. We also aimed to introduce changes that can possibly help to progress neuroscience education in future. Therefore, we describe the details of research projects and their learning objectives and show how these learning objectives were achieved during COVID-19 pandemic by using active and distance learning approaches in neuroscience education. The pandemic is still ongoing across countries, and therefore, it is necessary to explain and share these approaches, their advantages, and also shortcomings to promote developing effective measures in the teaching of SRPs in undergraduate neuroscience courses. In this article, the authors introduce the ways in which the COVID-19 outbreak have affected the teaching of SRPs and also propose hands-on and innovative solutions for the continuity of undergraduate teaching and learning in this time of crisis (refer to step 4 in Fig. 1).

**The Adaptive Measures to Maintain Practical Laboratory for Undergraduate Teaching during COVID-19 Outbreak**

At Monash University in Australia, from the beginning of semester 1 in late February 2020, officials have been forced to close the campuses in response to the growing coronavirus outbreak but switched classes to online teaching and learning to keep the courses open and running. By March 2020, course convenors and project supervisors redesigned delivery of SRPs for Undergraduate Students to maintain the subject during campus closure. In the following sections, we will describe the major changes and how active measures helped to maintain distance learning and achieve the learning objectives.

**Home-Based Short-Term Research Projects in Cognitive Neuroscience as a Replacement for Practical Laboratories**

[Figure 2](#) shows a summary of major changes in delivering the content and running the experiments in SRP in pre-COVID-19 period and during COVID-19 pandemic. The face-to-face sessions and experiments were all converted to online Zoom activities and home-based data collection strategies to do the following:

1. Meet the safety guidelines and required social distancing.
2. Run experiments at residential places even for those students facing the travel restrictions and therefore located in other countries or temporary hotels.
3. Achieve all learning objectives despite COVID-19 imposed restrictions.

There are two different types of teaching and learning activities in the proposed projects in cognitive neuroscience. First, theoretical framework, which was conventionally delivered in face-to-face tutorial sessions in which the background, aims, required hardware/software and experimental conditions and measurements, as well as the data handling and analysis, were introduced (Fig. 2; Table 2, column A). During COVID-19 pandemic, the structure and delivery of tutorials were modified (refer to steps 3 and 6 in Fig. 1) to comply with online delivery using technologically enhanced webinar approaches using Zoom (refer to step 6 in Fig. 1) platform. The second type of teaching and learning activities in these projects required conducting actual experiments in laboratory settings for the collection of research data.
data, which involved face-to-face participation of the students and project leaders. During COVID-19 pandemic, this aspect of the projects had to be modified so that students could conduct the experiments using specifically designed web-based cognitive tests from a simple and reliable setting at home.

In both pre-COVID-19 and during COVID-19 periods, each student had a dual role of an investigator and also a participant. In pre-COVID-19 period, students came to practical laboratories and performed cognitive tasks (as a participant) in research grade experimental setups and therefore all experiments were conducted in the laboratory. The programs for running cognitive tasks and data collection were written by the project supervisors (academics, who are also laboratory heads) and their higher degree research students who also supervised data collection sessions. This included software/hardware facilities for Stroop test and also an objective tool for assessment of balance (Neurocom Basic Balance Master Device) in project 1 and for Stroop test and WCST in project 2. During COVID-19 pandemic, the experimental procedure and schedule were modified and shared (refer to step 3 in Fig. 1) to enable running home-based experiments (distance learning) (refer to step 6 in Fig. 1). Table 2 describes the weekly schedule, requirements, and modes of delivery in pre-COVID-19 and the adaptive changes during COVID-19 pandemic.

Collection of Research Data for SRPs during COVID-19 Pandemic

In both projects 1 and 2 (Table 1), the PsyToolkit (21, 22) was used by the undergraduate students during COVID-19 pandemic to perform cognitive tasks and collect research data at their residential places. It is a web-based noncommercial free-to-use toolkit for demonstration, programming, and running of different cognitive and psychophysical experiments.

We used PsyToolkit because of the following:

1) It is developed by neuroscientists with solid evidence of excellent research in neuroscience.
2) It is freely available for students and academics.
3) The website includes programmable online cognitive and psychophysical experiments. Cognitive tasks can be modified to meet the experimental requirements.
4) Students can log in online and perform specific cognitive tasks, collect data, and save them for offline detailed analyses.
5) It runs on student’s browsers, without any plugins and without additional software requirement.

Project leaders prepared a step-by-step instruction for students to easily log in to Psytoolkit website, “add Stroop test (project 1) and WCST (project 2) on their experiment list,” “Run the test,” and finally “Save the results” (refer to steps 3, 5, and 6, Fig. 1) or predefined Excel file templates.

Assessments

In pre-COVID-19 practicals, students had to submit a written report and present a poster (oral presentation) to cover various aspects of the project. During COVID-19, in the first semester of 2020, the assessment was modified (refer to steps 8 and 9, Fig. 1) and students had to submit a literature review covering the background and the theoretical framework of their chosen topic and instead of poster presentation submit a research report (refer to steps 8 and 9, Fig. 1), with a format of a scientific research paper, to cover the methodology, results, and discussion of findings. In another cohort, online presentation of a scientific poster by each student group, using Zoom, was also implemented in the second semester of 2020. Posters were presented in prescheduled online sessions and three to four markers (academic and teaching assistants) marked the poster based on predefined criteria (a detailed marking scheme, which was also provided for students). Every member of each student group had to participate in the poster presentation and describe a part of the jointly prepared poster. In both pre- and during COVID-19 projects, the assessment was done on student-group work (4 students in each group prepared the reports and presentation on the same topic). Peer assessment was also conducted in which students within each group ranked the contribution of other group members and the final mark for each assessment was slightly modified depending on such ranking.

The procedure for preparation, submission, and assessment of literature review was the same between pre- and during COVID projects. Furthermore, there was no significant difference in students’ averaged mark or the quality of their work between the pre- and during COVID assessments. We included the online poster presentation in the second semester of 2020; however, the overall feedback from assessors indicated that, despite great efforts by teaching staff and students in organizing and presenting posters in predetermined Zoom sessions, the poster presentations in face-to-face sessions (pre-COVID) were more interactive, interesting, and engaging compared with the online presentations. In Pre-COVID projects, there were more face-to-face opportunities for students to meet each other and also discuss their drafts and progress with project leaders (in weeks 10–11). During-COVID pandemic, in week 10 and also in week 11, a formal online session was organized between student groups, project leaders, and teaching staff to discuss the progress and overall format of the poster presentations. Project leaders also encouraged students to organize within-group meetings and interactions between students to discuss and practice presentations; however, overall there were fewer opportunities for interactive practice and discussions. The face-to-face poster presentation in the pre-COVID period provided a great opportunity for students to experience a more formal presentation, akin to what is normally done in conferences, and interact with academics and teaching staff who marked the posters; however, this could not be completely achieved in during-COVID online presentations.

DISCUSSION

Achieving Learning Objectives of Neuroscience Practicals during COVID-19 Pandemic

Using the steps highlighted in the adaptive active distance learning diagram (Fig. 1) enabled our undergraduate students to successfully conduct two home-based SRPs and meet all quarantine and social distancing requirements stipulated by the University and Governmental guidelines.
## Table 2. Weekly schedule of teaching and learning activities

| Week  | Activity                                                                                          | A: Pre-COVID-19 Pandemic: Semester 1 (March-June 2017–19)                                                                 | B: During COVID-19: Semester 1, 2020 (March-June 2020)                                                                 |
|-------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| Week 1| Introduction to the projects (10–15 min)                                                         | Brief presentation of the project outline, goals, requirements, and assessments (presented by the project leaders in a tutorial room). Only enrolled students attended. Students received a hard copy of the ethics explanatory form and signed a consent form and also received a printed explanation of the requirements for cognitive tasks and experiments. Students were asked to study the data structure and read the recommended scientific papers which used similar data analysis. Students received a hard copy of the ethics explanatory form and signed a consent form and also received a printed explanation of the requirements for cognitive tasks and experiments. Students were asked to study the data structure and read the recommended scientific papers which used similar data analysis.             | Same materials were presented through online Zoom meetings by the project leaders (step 6, Fig. 1). Same as the pre-COVID-19 pandemic. Same as the pre-COVID-19 pandemic. Students received full instruction for accessing and downloading a web-based computerised version of the cognitive tasks available online at PsyToolkit website (steps 3, 5, 6, and 7, Fig. 1). Students received explanations about the cognitive task requirements and procedures for setting their computer and experiments through online meetings (steps 5–7, Fig. 1). Same as the pre-COVID-19 pandemic. Same as the pre-COVID-19 pandemic (steps 3, 5, and 6, Fig. 1). |
| Week 2| 1st Tutorial Session (2-hour): Introduction of the goals, hypotheses, and theoretical background    | Presented face-to-face by the project leaders. Students were encouraged to make groups of 4 (managed by course website, Moodle) for preparation and presentation of the assessments (written reports). Students received a hard copy of the ethics explanatory form and signed a consent form and also received a printed explanation of the requirements for cognitive tasks and experiments. Students were asked to study the data structure and read the recommended scientific papers which used similar data analysis. Students received a hard copy of the ethics explanatory form and signed a consent form and also received a printed explanation of the requirements for cognitive tasks and experiments. Students were asked to study the data structure and read the recommended scientific papers which used similar data analysis.             | Presented through Zoom by the project leaders. Presented through Zoom by the project leaders. Same as Pre-COVID-19 (steps 6, 7, and 8, Fig. 1). Same as Pre-COVID-19 (steps 6, 7, and 8, Fig. 1). Same as Pre-COVID-19 (steps 6, 7, and 8, Fig. 1). Same as Pre-COVID-19 (steps 6, 7, and 8, Fig. 1). Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. Same as pre-COVID-19 pandemic. |
Our systematic approach (Fig. 1) in addressing the problem has embraced the recently suggested approach (23) for development of a flexible active and distant learning in neuroscience education. Considering different stages of COVID-19 lockdown and unpredictability about the partial or complete reopening of research facilities, there is a crucial need for developing a comprehensive plan for more flexible approaches in neuroscience education, which could be easily adapted by other institutions and student cohorts. These proposed models have the capacity to fast-forward neuroscience education at every level during COVID-19 pandemic and even postpandemic.

In a broader sense, the new approach is an example of home-based research data collection fitting the concept of remotely conducted research [tele-research (TR)]. Technological advances in the form of wearable sensors and mobile phone applications can greatly facilitate supervised TR. TR’s potential to transform the neuroscience educational and research needs could not be fully achieved without a complete understanding of the apparent advantages and disadvantages (barriers and enablers) by the stakeholders of tertiary education and research.

**Advantages and Disadvantages of the New Approach**

Pre-COVID-19 pandemic, all research data were collected in laboratory settings under the direct supervision of experienced researchers. A potential caveat in home-based experiments was that the entire data collection and therefore its reliability and validity were dependent on students’ competence and devotion in following the details of the procedures and guidelines. Detailed analyses of results by project leaders indicated a great reproducibility and consistency in data collected by the majority of students. The results of cognitive tests were closely comparable between the laboratory-based and home-based experiments indicating that students followed the guidelines and the required procedures for a reliable data collection. Even the international students who were positioned in another country and could not come to Australia due to travel restrictions were able to collect and share a complete set of the required data. This indicates that although the project becomes more dependent on students’ management and skills in organizing the home-based data collection, such student-centered project can enormously strengthen students’ ability for problem solving and improving their organizational skills to achieve a scientific and educational goal. The advantages of such student-centered education and active learning have been confirmed in other studies (23, 24). Feedback from project leaders, teaching assistants, and students indicates that students’ active participation should be closely monitored by weekly meetings and interactions. Some students might feel disconnected and unsupported by extensive changes due to student-centered active learning (25). In the case of our neuroscience projects, the necessity for setting and organizing experiments at home and reliance of the project on students’ performance could have been overwhelming for some students, particularly at the time of lockdown and social distancing. Therefore, we organized at least two online Zoom sessions per week (one with the project leader and one with the teaching assistants) to discuss the requirements and address students’ questions and in practice keep them engaged.

Home-based invigilated data collection (HIDC) could be a solution for improvement of the reliability and validity of the recorded data. In this method, the investigator can arrange an online meeting through Zoom or other online platforms with the participant to invigilate all pre- and postintervention data collection and management. Although there is no record of HIDC in the literature pertaining to the educational practicals or research projects for undergraduate students, the method has been introduced for remotely invigilated online exams (26).

In conclusion, despite missing the opportunity for the face-to-face interactions between students and teaching staff, we believe almost all learning objectives were successfully achieved by transitioning the SRPs in cognitive neuroscience to a home-based practical project. These learning outcomes can be summarized as follows: 1) define tangible scientific questions, understand its theoretical background and envisage experimental approaches to address these questions. 2) Understand the design of a research project (such as counterbalancing) and the required guidelines and measures to collect reliable data. 3) Organize and prepare a research setup for data collection based on predefined rules and schedule. 4) Understand the inherent variability in biological measurements. 5) Understand statistical approaches to analyze data and interpret them to gain insight into the effects of various factors on brain functions. 6) Improve scientific writing and communication of findings. 7) Improve group work for achieving a common scientific goal. Students’ devotion and meticulous care about running the experiments at home and collecting data were remarkable. They were excited about the results and expressed it during follow up Zoom meetings. Students’ feedback at the end of the semester indicated their satisfaction and enthusiasm about running these experiments at home. Students’ feedback indicates that even during inevitable lockdown period running these experiments and being involved in a practical research project including analyzing, interpreting, and presenting their own data was an interesting experience (refer to steps 9 and 12, Fig. 1). A limitation of our feedback collection was that it was not systematically done and therefore could not be quantified. We need to implement more quantifiable approaches for collection of feedback to enable comparisons within and across projects.

Considering the on-going issues with the pandemic, these adaptive measures have provided a great opportunity to run SRPs and maintain teaching and learning objectives for undergraduate students. The possibility for running them in various countries and settings (home, school, dormitory, hotels) brings a great flexibility in maintaining neuroscience SRPs and in achieving their learning objectives while meeting the necessity of social distancing. These adaptive approaches, although imposed by an unprecedented pandemic, might lead to novel techniques in student-centered learning activities.

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