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Educational Probe for Developing Online Education: A Case of Online Problem-Based Learning in Design Education in India

Y. Hayama [1,✉] and H. Desai [2]

[1] Politecnico di Milano, Italy, [2] MIT Art, Design and Technology University, India

✉ yasuyuki.hayama@polimi.it

Abstract

The COVID-19 pandemic brought challenges and opportunities for higher education and one of the important areas was online education. Especially in design field, Online Problem-Based Learning has emerged as a promising method. This paper explores the potential of online-PBL and how it can be developed through a prototype approach. An action research in Indian HEI shows insights regarding the potentiality of online-PBL and application of a prototype approach to educational development activities. A concept of "educational probes" was proposed as a method to design educational program.

Keywords: design education, digital learning, design management, educational probes, online problem-based learning

1. Introduction

1.1. Challenges of Higher Education Institutions in Design Field

Teaching and learning conditions in higher education institutions (HEIs) have been dramatically changing, leading to demand development in teaching practices and enhanced student learning experience (Roxå and Mårtensson, 2008; Biggs and Tang, 2011). Recently, a growing number of researchers and professionals have begun to argue for educational strategies to transform traditional methods. They recommend combining frontal teaching practices with student-centered processes that stimulate active learning within supporting environments designed to leverage the advantages of digital technology by engaging students to resolve real-life problems and activating suitable learning assessment strategies (Brandon, 2004, Sancassani et al., 2019). Under these fast-changing teaching and learning experiences, a core implication includes a shift of focus regarding teacher's responsibility - a consequence of a paradigm shift from "teacher-speaker" to "teacher-designer." This refers to the transition from responsibility for a correct and exhaustive presentation of the contents to responsibility for designing and managing an experience focused on supporting the achievement of the Intended Learning Outcomes (ILOs) (Sancassani et al., 2019). Moreover, after the COVID-19 pandemic, which precipitated a switch to online education, HEIs have been struggling to develop educational practices, especially in teaching practical and skilled-based subjects, such as design and engineering (Gill et al., 2020). Given these conditions, faculties in design discipline in HEIs should develop and deliver educational environments and experiences for students to build and apply their knowledge.

1.2. Developing Online Problem-Based Learning

Problem-based learning (PBL) as an educational strategy has attracted attention across disciplines in higher education. Its rationale lies in its compatibility with modern educational goals, such as the education of self-directed and lifelong learners who can collaboratively solve real-life problems (Barron et al., 1998; Biggs and Tang, 2011; Hung et al., 2008). Given its pedagogical rationalities, researchers often emphasize key elements of PBL, such as being able to communicate and collaborate to solve complex problems, being able to adapt and innovate with respect to new demands and changing situations, and being able to use technology to build new knowledge.

As a consequence of the recent change in educational conditions to digital environments, online educational activities, such as online PBL, are gaining attention as potential providers of appropriate learning experiences and outcomes (Hikamah, 2021). Researchers investigating online PBL have examined learning outcomes as well as the use of technological characteristics to support PBL (Valaitis et al., 2005). A wealth of extant research has prevailed many aspects and elements of PBL as collaborative learning, for example, interpersonal skills, communication skills and collaboration skills (e.g. Prince et al., 2005; Schmidt et al., 2006), as well as the successful factors of online PBL (Saqr et al.,2020). However, the potentiality of online PBL and how its curriculum could be developed have rarely been investigated - especially in the context of a rapidly changing digital environment.

Therefore, the authors propose that online PBL could be a potential harbinger of novel educational activities and experiences. The article also implies that a prototype approach could be advantageous in the educational development of online PBL courses. In this study, two main research questions were addressed. First, how can online PBL have a potential impact on opening up new educational activities and experiences? Second, how can the prototype approach have a positive impact on making online PBL effective? We report the application of a prototype approach to design management program at the MIT Institute of Design (MIT ID) in India. This article presents a case study of online PBL aimed at introducing a specific theme of design driven innovation (DDI) in higher education in India.

2. Methodology

2.1. Context

The COVID-19 pandemic created enormous challenges for HEIs, educators, and students, impacting the design of educational activities, schedules, attendances, deliveries, examinations and assessments, and student progression (Gill et al., 2020). However, it also provided a unique opportunity to experiment with novel educational practices involving greater use of online learning and digital devices and tools. To maximize these opportunities, MIT ID reacted positively - and quickly - to implement new educational activities by applying online and remote modes.

2.1.1. Design Management Education at MIT ID

MIT ID is among the largest design institutes in India, offering a wide variety of design programs at the bachelor's, master's, and PhD levels. In a two-year master's program in design management, both management and design contents have been provided a holistic manner. As design management is a dynamic and evolving field, providing cutting-edge content is essential to expose the students to diverse approaches and concepts. Under the two-year master's program, a new module on design driven innovation (DDI) (Verganti, 2009, 2018) is being considered as a next core educational practice in order to develop new, relevant programs for the fast-evolving online education space. DDI is a comparatively new paradigm and to appreciate its value and relevance, one needs to have a prior understanding for design process and principles of human and user-centered design. Further, DDI is an approach for business innovation and requires a prior understanding of business fundamentals, marketing management and consumer behaviour and related topics. Hence, nine students were selected from the batch of the design management program as they fulfilled the required pre-requisites to learn the concept of the DDI effectively. Further, such a study was carried out for the first time, the batch size was kept limited to nine students. All the students of the master of design management were part of the study.

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2.1.2. Educational Challenges in Designing and Delivering Online Programs

The main challenges faced by the MIT ID staff during the planning and preparation phases included developing online contents and methodologies with limited training, experience and preparation time. Additionally, faculty members teaching practical and skills-oriented courses found it difficult to provide students with a deep understanding of new content of DDI and its practical applications via online and remote settings. This particular challenge highlighted the opportunity to apply online PBL, collaborating with teaching staff overseas who possess a shared understanding of the concept of DDI. At the same time, as the application of new learning content and method to an existing master's program might include unpredictable risks, the faculty members needed an approach to minimize such risks to ensure their quick applicability and confirm their effectiveness for further development of the online curriculum. It is concluded that the faculty members apply a prototype approach to fulfil all the requirements, as explained below.

2.2. Prototype Approach

To develop a new online teaching and learning program, a prototype approach was applied (Wensveen and Matthews, 2014). A prototype refers to "any representation of a design idea, regardless of medium"(Houde and Hill, 1997). Wensveen and Matthews (2014) distinguished the role of prototypes as vehicles for research on, for, and through design. In this study, "the prototype was applied as a means of inquiry." In this mode, the prototypes are developed and deployed as instruments to collect, record, and measure phenomena that are under investigation for creating design-relevant data.

A typical example of this type of prototype used in design research is "technology probes" (Hutchinson et al., 2003), which are functional prototypes informative of users' way of use - and neglect - of technologies; they are also technological interventions in the target users' ordinary communicative practices. In the context of educational design processes, prototypes play an important role in developing research-based solutions for complex problems in educational practices (Plomp, 2013). Design researchers in educational practice can obtain data on actual participation and refine course content and delivery through gradual and iterative prototyping processes. In other words, with respect to the prototype approach, "educational probes" can be considered as an effective tool used to gain insights in real world live scenarios.

Table 1. Prototype framework (elaborated by authors)

Aspects	Choice	Descriptions
Basic conditions	-	• Conducted from 15th till 18th December, 2020 (three days workshops plus one day of 17th was allocated for home work) • Sub-educational course under the Design Management master's program • Nine students and three teachers participated in the program • Three days prototype educational program
Timeline of the activities	-	• Day 1: Lectures and workshops (Design research) • Day 2: Lectures and workshops (Design Driven Innvation) • Day 3: Workshops, presentation and final remarks
Learning environment	Online	• Online-based educational setting • Students and teachers participate online separately • Online tools (MIRO, MS Teams, Google meet)
Teaching strategy	Problem-based learning	• A real-world problem setting: new product development for an Indian food company • Group work by two teams • Frequent feedback by teachers
Educational content	Design driven innovation	• A new educational content: Design driven innovation • Basic concepts and approach were taught during the program • A few toolkits were provided for group work

In this research project, an educational prototype was designed based on three aspects: learning environment as online, teaching strategy as PBL, and educational content as DDI. Three faculty

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members, including the two authors, designed this as a three days workshop for the master of design management program. Nine students of the second year batch participated in the workshop, which was conducted using digital educational tools, such as MIRO, Microsoft Teams, and Google meet, where students could collaborate and interact virtually. The teaching strategy was PBL, in which a real-world problem was set as a common challenge for each team. Specifically, a hypothetical setting of an Indian food company was used, and students were required to work on a new product development assignment. Teachers frequently interacted with each group, giving them feedback and assistance to help them better understand the contents and achieve new product development. Design driven innovation (Verganti, 2009, 2018) is an innovation approach for new product development, and is different from the market-pull or technology-push approaches. The workshop introduced this approach to enable participants to work on a new product development challenge. These three pillars were tested as an "educational probe" from the perspectives of both faculty members and students. A detailed description of the framework is presented in Table 1.

2.3. Action Research

Guided by the prototype method to design an online PBL program, the data were collected through action research (Milles, 2000) by the authors' empirical research actions. Instead of merely explaining, predicting, and/or controlling educational phenomena, which are the goals of traditional educational research, action research allows teacher-researchers to act and affect positive educational changes.

2.3.1. Deciding on an Area of Focus

At the beginning of the action research, three main focus areas were defined to link the ideas of educational intervention to the actions (Milles, 2000). These three areas are stated below, aligning with the prototype framework that was developed previously. Two aspects were carefully researched in each of the three areas: 1) evaluations of the learning experiences of the educational prototype, and 2) expectations for future educational development.

- Online teaching and learning experience
  - How can students effectively collaborate and achieve a high learning experience in an online setting? (1. Evaluation of learning experiences.)
  - How can online curriculum be developed more effectively or meaningfully? (2. Expectations for future educational development.)
- Problem-based learning experience
  - How can the PBL approach engage students in real-world problems online? (1. Evaluation of learning experiences.)
  - How can the PBL curriculum support student learning more effectively? (2. Expectations for future educational development.)
- Design driven innovation contents
  - How can new learning content complement and enhance the overall master's course curriculum? (1. Evaluation of learning experiences.)
  - How can new learning content be developed to be more effective and meaningful? (2. Expectations for future educational development.)

2.3.2. Data Collection

Two qualitative data collection techniques were applied as the research method. The primary participant observation was conducted by the authors as active participants. As active participant observers, the authors engaged in teaching activities and observed activities, people, and physical aspects (Milles, 2000). Students' engagement in online settings, degree of collaboration, and level of understanding about the contents were carefully observed. Meanwhile, the authors actively observed any potential improvement in the new online curriculum in the future. Online-survey was delivered to all the students at the end of the project, requiring them to rate on a scale of 1 to 5 their level of satisfaction with each element of the three focus areas. Additionally, detailed and candid answers were requested to assess their opinions about the learning experience and to propose improvements for future development.

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3. Results

With respect to each focus area, qualitative data were collected through participant observation and survey. The results positively support the online PBL experience. Additionally, the online prototype application delivered several insights for educational development for the future, which would enable the introduction of new learning contents and teaching and learning experiences to the university curriculum.

3.1. Online PBL Prototype Learning Experiences Evaluation

3.1.1. Evaluation of Online Learning Experience

High student engagement in the online learning experience was confirmed via both observations and survey. Thanks to the PBL, students had many opportunities to collaborate with each group member. The authors observed that a digital tool, such as MIRO supported their collaborative engagement effectively, allowing them to work together on the same work sheet visually and actively without the frustration associated with the remote mode. Frequent feedback and interactions with teachers or staffs played an important role in facilitating students' collaborative engagement. During the interactive moments, students sometimes faced difficulty in understanding and applying new concepts properly, so that support by teachers or staffs boosted their understanding and work progress effectively.

According to the survey results, the online learning experience was evaluated by the students as a positive experience. A total of 86% of them highly evaluated the collaborative experiences among students and teachers and the quality and frequency of interaction. They shared that interactive brainstorming conversations, supported by digital tools, facilitated effective collaborations. Additionally, energetic engagement by faculty members was evaluated positively and made their learning experience explorative and fun.

3.1.2. Evaluation of Problem-Based Learning Experience

A real-world problem setting accelerated the deep understanding of new learning content and facilitated collaboration among students. In this prototypical learning activity, a specific problem for Indian food company was assumed to facilitate collaborative learning experiences. The concrete problem not only facilitates a clear understanding of the new learning contents, but also encourages students to apply the theory to a practical business situation. Moreover, the authors observed that each student taught and learned from each other during group discussions when they tried to understand the real challenge and how to apply the conceptual frameworks to it. This collaborative learning can be highlighted as a fundamental characteristic of problem-based learning, where students stimulate their deeper understanding through "doing" practices that help each other.

The survey results revealed that more than 60% of students evaluated PBL experience in an online setting. Supported by some toolkits to facilitate group activity, students could apply the conceptual framework of design driven innovation to the specific problem. Some students commented that the time was limited to three days, so it was difficult to achieve a deeper understanding of the concepts and its application to a real-world problem.

3.1.3. Evaluation of New Design Driven Innovation Content

The new learning content of design driven innovation strongly complemented the entire master's program. In particular - as it is a well-constructed theoretical view with respect to innovation by design - the content strongly enhanced students' overall understanding of innovation management. As the two-year master's program focuses on design management, the theoretical perspective that can bridge design and innovation management itself is the fundamental learning component. Especially for designers, the content of design driven innovation is crucial for acquiring deeper knowledge of innovation management from a design standpoint.

In fact, 100% of the students highly valued the content, which they found immensely relevant to the entire master's design management program. The survey results highlighted that the content of design

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driven innovation was extremely practical for industry-oriented projects, which boosted the learning experience of the PBL approach.

Table 2. Results of the learning experiences of educational prototype

Area of Focus	Observation by the authors	Responses and feedback by students

Online	• High student engagement under the condition of frequent feedback by faculty, supported by digital tool such as MIRO	• High evaluation (88%) of collaborative experiences among students and teachers
		• High evaluation (88%) of quality and frequency of faculty interaction
		• Actual comments from students' feedback
		  • "Exploratory, interactive, and fun"
		  • "The tools used for brainstorming and learning helped well in collaboration"

Problem-based learning	• Effective communication and strong collaboration in each online session
	• Facilitating learning content comprehension through mutual support
		• High (63%) and medium (37%) evaluation of the online PBL experience
		• Actual comments from students' feedback
		  • "Solving a real-world problem offered a practical implementation opportunity to apply learnings"
		  • "Shortage of time adversely impacted depth of PBL"
		  • "Templates supported learning experience"

Design driven innovation	• High learning impact for students
	• Strongly complements the master's program
		• High relevance (100%) for the master's program
		• Actual comments from students' feedback
		  • "Supportive for solving future real-world problems"
		  • "Enhanced the overall learnings of the master's program"

3.2. Expectations for Future Development of Online PBL

Thanks to the prototype approach, some explorative insights and expectations for future educational development have d from participant observations and survey. Results are shown in Table 3.

3.2.1. Expectations for Online Learning Experience

A few insights were received for future development of online educational programs. First, online education enabled remote collaborations with overseas teachers, implying more flexible and easier collaborations with foreign scholars and practitioners than in traditional classroom settings. Such freedom and flexibility provides teacher-designers more options to design educational curriculum. However, we recognized that trusted and close relationships among faculty members were crucial when designing and conducting a new online educational activity online. Second, the survey results implied that additional physical activities could supplement and enhance learning experiences. Even though students can learn and collaborate effectively in an online setting, it will not decrease the importance of traditional physical interactions. This implies that several optimal combinations of online and physical educational practices could be considered for future educational development.

3.2.2. Expectations for the PBL Experience

Several expectations for PBL were analysed for future development. First, a longer period of educational activities could extend students' learning experiences. The three days prototype was inadequate for optimal absorption of the learning content, and the expectation for a longer course was high. Second, in addition to group activities, a few supplementary individual activities were also preferred to facilitate knowledge acquisition. The importance of individual work to tackle new learning concepts should not be overlooked, and in this regard, traditional personal homework could be a learning driver. Finally, a few students reported the importance of the selected real-world problem. The more challenging and trendy the topic, the more it motivated the students to learn. In this sense, collaborations with actual companies could expose students to practical situations where they would not only learn from the cases proposed, but also grow as professionals by devising and proposing solutions to problems.

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3.2.3. Expectations for New Learning Contents

Some potential combinations among the content of design driven innovation and other relevant themes appeared as an entire, coherent learning program. For instance, creativity enhancement and design thinking could be highly supplemented with the theme of design driven innovation. A few students commented that brand strategy could be useful supplemental content to collectively enhance the understanding of design driven innovation. Furthermore, additional business-oriented contents such as entrepreneurship and more business terminologies were also proposed. These results indicate that further workshops on topics under design management can be undertaken.

Table 3. Results of future expectation for educational development

Area of Focus	Observation by the authors	Responses and feedback by students
Online	• Possibility to collaborate with overseas teachers and remote locations • Importance of close relationships among faculty members	• Virtual collaboration was manageable; however, physical collaboration would have been more fruitful • Small activities to understand concepts • More coherent usage of the online medium (e.g., SNS)
Problem-based learning	• Real projects by companies could have higher outcomes on learning experiences	• Longer course duration enhances learning impact • Individual projects could deepen understanding in longer courses • Challenging and trendy real-world topics could motivate students • Further interactions with experts and users could support learning experience
Design driven innovation	• Combination with other educational topics (e.g., Creativity Enhancement, Design Thinking)	• Real-world application of methodology could enhance learning experience • Other related contents could be included in the course (e.g., brand strategy, entrepreneurship) • How to run a business pitch

4. Discussion

This article presents an action research regarding the educational development of online PBL in an Indian HEI. This study explores the potential of online PBL within design education and how it can be developed through a prototype approach in a rapidly changing educational environment.

4.1. Potentiality of Online PBL after COVID-19

The first key finding is that online PBL could have a potential impact on opening up new educational activities and experiences. As the recent COVID-19 pandemic has caused a shift to online teaching and learning, higher educational institutions and teachers have been facing challenges in developing new types of educational activities leveraging the effective and practical utilization of online environments. This study showed that online PBL could provide high learning experiences where students could engage in a specific, real-world problem and collaborate with support from online and digital technologies. The results were especially meaningful for subjects such as design and engineering, where practical and skill-based content and learning are particularly required.

Owing to recent advancements in online and digital technologies, costs and inconveniences to interact with each other remotely have dramatically decreased. Consequently, collaborative educational activities, such as PBL have become simpler and easier to design and implement. This radical change in the learning environment driven by online and digital technologies may provide greater freedom and flexibility for teacher-designers to design curricula. The potential of online PBL could be explored and developed further through additional educational experiments.

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India, experiencing an exponential growth in adopting digital technologies in education, has witnessed phenomenal growth in the last few years. This growth was further accelerated by COVID-19 and online education has seen a wider adoption. Online education has made education accessible and affordable to large number of students and professionals. Although there are still challenges in terms of lack of trained faculty and good quality content. This online PBL serves as a good starting point to enhance the overall learning experience and engagement of learners.

4.2. Effectiveness of the Prototype Approach for Educational Development

Second, the study revealed that a prototype approach could have several advantages for educational development in terms of exploring core components of teaching and learning experiences in an open-ended manner. In this study, future expectations and insights for developing a new curriculum emerged in each of the three focus areas, as discussed above.

The results imply that the three days educational program functioned as a "prototype as means of inquiry," so that data relevant for designing a future firm educational program were properly collected. Referring to the expectations and insights found in the program, we as teacher-designers could design a much better new online curriculum without incurring major risks (i.e., neither investing in a specific instrument nor conducting large-scale experiments). Instead, a prototype approach in educational development allows teacher-researchers to gather design-relevant data as rapidly and flexibly as possible. These characteristics of the prototype provide advantages for educational development, especially under circumstances where educational conditions are dramatically and rapidly changing with unexpected events, such as the COVID-19 pandemic. Teacher-designers could take advantage of the prototype approach when designing their own new curriculum.

The students found the workshop to be valuable both because of the content (DDI) and the approach and pedagogy (online PBL). Also as the students got an opportunity to work on a real life example, it enhanced their confidence to apply the learnings in a practical context.

4.3. Educational Probes

We could describe these prototype functions in educational development as "educational probes," referring to the functional aspects of "technology probes" (Hutchinson et al., 2003). Hutchinson et al. represented the technology probes as follows:

> *"Technology probes are simple, flexible, adaptable technologies introduced into families' homes with three interdisciplinary goals: the social science goal of collecting data about the use of the technology in a real-world setting, the engineering goal of field-testing the technology, and the design goal of inspiring users and designers to think about new technologies."*

By referring to the definition and its goals, "educational probes" can be described as functional prototypes applied to educational development environments as a kind of research instrument. Educational probes' goals are derived from two interdisciplinary perspectives: the educational goal of collecting data about an intervention of an educational program in a real educational setting, and the design goal of inspiring students and teacher-designers to think about new educational activities.

These interdisciplinary aspects of educational probes could provide teacher-designers with several advantages. First, they could provide teacher-researchers a high possibility of developing new educational programs rapidly and flexibly with low risks. Using this method, teacher-designers can collect relevant data for students' learning experiences in a real educational setting. Second, some unpredictable insights can be discovered for future educational development. Through a combination of action research and educational probes that should be properly designed before conducting educational experiments, teacher-designers could not only confirm their hypotheses on the educational program under investigation, but also receive valuable insights through careful observation and survey feedback from participants. Lastly, these advantages of educational probes could play a pivotal role under the conditions of rapid and dramatic changes in educational environments in higher educational institutions in order to minimize the risks of challenges of

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designing new educational programs and to keep evolving cutting-edge educational programs for students who require advanced knowledge and learning experiences at practical levels.

5. Conclusions

We believe that this study makes three main contributions. First, the effectiveness and potential of online PBL have been elaborated, especially under the rapidly changing conditions after the COVID-19 pandemic. Especially in practical and skill-based subjects, such as design discipline, HEIs and educators are facing challenges in adapting to a rapidly changing educational environment oriented to online mode and providing high-quality learning experiences to their students. Online PBL could be an essential educational approach for those faculties to develop new online curricula that could facilitate further understanding of new learning contents collaboratively with student-faculty interactions and fulfill practical needs of students and industries. Second, a prototype approach has been certified as an effective development tool for educational development. Educational development is still a growing research area that needs to be developed further. Especially in such a dramatically changing context, knowledge about how a new educational curriculum could be successfully designed and delivered to students should be accumulated more in academic fields. A prototype approach to minimize risks and maximize effects has been certified and proposed as a potential approach for educational development. Finally, the concept of "educational probes" has been briefly proposed. This concept could provide several advantages for educational researchers and designers, allowing them to focus on the interdisciplinary aspects of educational development - both educational and design aspects. Consequently, both education scholars and design scholars could collaboratively tackle knowledge creation on challenging topics regarding educational development through an interdisciplinary lens of educational probes.

Further research activities that would be interesting to explore are as follows: First, online PBL and other online teaching methods should be actively and widely investigated in both design disciplines and other practical and skill-oriented disciplines, such as business management and engineering. As Amundsen and Wilson (2012) indicated, educational development still remains a developing field; hence, further progress in knowledge on educational development is strongly required in the rapidly changing educational environment for both HEIs and students who are eager to acquire practical knowledge. In this line, the authors continue to develop online curricula applying the online PBL approach more extensively, making use of fundamental implications, and try to develop other types of online educational methods as well. Second, the prototype approach for educational development should be investigated further. In this line, the concept of "educational probes" could provide fundamental advantages and analytical viewpoints to tackle both theoretical and practical facets of educational development.

This study had several limitations. By restricting itself to the specific single action research with a small number of participants in an Indian HEI, it may not have attained universal results and insights for every situation for teacher-designers who try to build their own online educational practices. Further research will be required to verify both the utility of online PBL and the prototype approach for educational development. A comparison between online and face-to-face PBL in the sense of goal achievement would be a possible research avenue. Furthermore, this study proposes a few insights - these are first insights, but not exhaustive - for online educational development and prototype approach applications.

Finally, we hope that scholars in multiple disciplines, such as design, management, engineering, and education, will engage in research and practice to establish academic inquiries and knowledge on educational development.

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