Technical Note

University-level Mathematics Pre-enrollment Education Combining Individual and Group Works in a Perfectly Distributed Asynchronous Environment

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Abstract: The Institute of Humanities at Shinshu University has instituted an e-learning system to provide mathematics and statistics pre-enrollment education (PE) to applicants who passed the 2020 examination for candidates recommended for the faculty of engineering. This study presents this PE's results. PE can be categorized into individual work and group work. In individual work, accepted applicants answer mathematics and statistics problems provided by the University e-Learning Association. In group work, they search solutions to such problems by consulting with the faculty of engineering's undergraduate students and other accepted applicants; a group representative submits the answers. We show that accepted applicants can maintain self-efficacy even in perfectly distributed asynchronous PEs.

Keywords: pre-enrollment education, mathematics education, e-Learning, CSCL, self-efficacy

1. Introduction

The Ministry of Education, Culture, Sports, Science, and Technology (MEXT) is currently promoting a reform to facilitate the transition between high school and university education. This reform requires a multi-faceted assessment of three academic proficiency elements, including initiative, during universities' selection of individuals for admission. Moreover, this reform requires universities to conduct educational activities for various accepted students to help them transition from high school education to higher education as well as to improve their abilities. Particularly, MEXT requires each university to actively provide pre-enrollment education (PE) for maintaining students' motivation to study after their early acceptance.

In response to this guideline, many universities now provide PE, and these efforts' results are being reported in academic journals. To provide remedial education for improving the self-efficacy of individuals planning to enroll, many universities provide PE for applicants who have been accepted early, including applicants who have passed admissions office screening and examinations for recommended candidates.

The current study's authors conducted a survey about taking mathematics and science courses in high school [3]; survey participants included students newly admitted to Shinshu University, and the authors endeavored to ascertain the characteristics of these admitted students. This survey led the departments responsible for first-year education to provide PE to support individuals planning to enroll in the university. This PE aimed to alleviate pre-admission students' concerns, overcome geographical and temporal constraints, and maintain or heighten their self-efficacy with respect to learning. This study reports the PE effects and suggestions for applicants who passed the 2020 examination for candidates recommended by the faculty of engineering.

2. Study Position

2.1 Related Work

Recent findings concerning PE have been described in academic journals or magazines: these include analysis results of students' current status [4], [5], results on education practice combining face-to-face and distributed environments [6], [7], and results on education practice using a learning management system [8]. Among these, Otsuka et al.'s [8] work is closest to this research in terms of distributed-asynchronous PE. They used Moodle to conduct PE, including discussions, learning outcome presentations, and self-assessments. The presence of other participants seemingly enabled prospective students to maintain their learning motivation through instructor-student interactions and interactions between students. However, their study did not assess self-efficacy, which is the focus of our study. Many studies investigated the relationship between self-efficacy and motivation to learn (e.g., Ref. [9]). Moreover, Saeid and Eslaminejad [10] identified a relationship between students' self-directed learning readiness, academic self-efficacy, and academic motivation. Therefore, it is necessary to assess self-efficacy in distributed-asynchronous PE.

We used only a Moodle-based learning management system

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named eALPS for our PE and combined individual and group works. The applicants presented their learning outcomes, discussed mathematics/statistics assignments, and observed other applicants' learning outcomes in eALPS. Then, they presented the group's answers obtained through discussions with other applicants based on the facilitation of undergraduate students. This study contributes academically by quantitatively demonstrating the possibility that self-efficacy can be maintained in perfectly distributed asynchronous PE.

2.2 Theoretical Foundation

Shinken-Ad. Co., Ltd. [11] cites five aspects of PE's emphasis during educational reform to facilitate the high school-university education transition:

1. Not deviating from the new learning methods from high school;
2. Associating high school-level learning with university-level learning and increasing learning motivation;
3. Content providing a sense of fulfillment through results, feedback, and so on, and requiring active involvement;
4. Content fostering interest in academics and preparing students for enthusiastic learning post-admission; and
5. Having ability to share and use PE results on campus (e.g., for post-admission student support, institutional research, and high education quality).

Considering these five points and findings on the relationship between students' self-efficacy and group work [12], we focused on group work by accepted applicants [8] and use of student tutors [6] in our PE. Moreover, our PE was designed based on Keller's ARCS model [13]. This model presents four aspects of what instructors should do to improve and maintain learner motivation: attention, relevance, confidence, and satisfaction. **Table 1** shows the relationship between this model and PE. The elements described in this table are explained in Section 3. The ARCS model can be effective for motivating students to improve their attitudes toward mathematics learning in online environments [14]. We considered this model's application to be potentially effective because our PE focused on motivating applicants and enhancing their self-efficacy.

Table 1 Relationship between the ARCS model and pre-enrollment education (PE) elements.

ARCS	PE elements
Attention	* Being able to communicate with other successful applicants before admission * Providing issues to tackle individually or in groups * Using language that will be of interest to successful candidates (e.g., "Earlier than those who passed the general entrance examination" and "Master course")
Relevance	* Providing materials for helping applicants learn at Shinshu University * Providing open-ended challenges involving familiar topics
Confidence	* Being able to work step-by-step on assignments while starting with first-year high school-level questions * Tutors helping applicants to succeed * In group work, instructors highlighting good points and identifying improvement no matter what answers are submitted
Satisfaction	* Instructors giving awards to applicants based on learning outcomes * In group work, instructors' making feedback available for all groups and applicants

3. PE

3.1 PE Overview

Since this PE is newly framed by the departments responsible for first-year education, small-scale implementation was emphasized. Accordingly, PE was implemented among 51 applicants who passed the examination for candidates recommended to the faculty of engineering (accepted applicants from vocational education-related disciplines were excluded). Considering the circumstances of applicants' high schools, PE-related participation was voluntary. Because of geographical and temporal constraints, all learning tasks were conducted on eALPS.

This high school mathematics and statistics PE featured units to facilitate learning in the first year. Until December 2019, applicants tried a limited form of PE and indicated their consent by responding to a participation-related survey. The survey asked for their e-mail address, eALPS screen name, mathematics courses attended in high school, and self-rated understanding of mathematics [3].

In January 2020, complete PE was provided, which lasted until the end of March. During that period, the applicants performed "individual work" by themselves freely and "group work" with several applicants and the student assistant (SA) from the faculty of engineering. Furthermore, appropriate instructor feedback was provided in response to efforts of the accepted applicants and SA.

3.2 Individual Work

Individual work included mathematics problems (level: high school; years [Y] 1–3) and analyses of statistical data materials provided by the University e-Learning Association [15]. Five senior students from the department of mathematics at the faculty of science at this university selected and checked the problems. They were working to receive teaching licenses. **Figure 1** lists the five prepared courses:

1. Master course in high school mathematics basics: quadratic functions (Y1), graphs and measurements (Y1), higher-order equations (Y2), and exponential and logarithmic functions (Y2);
2. Master course in functions and limits: trigonometric functions (Y2), graphs and equations (Y2), number sequences

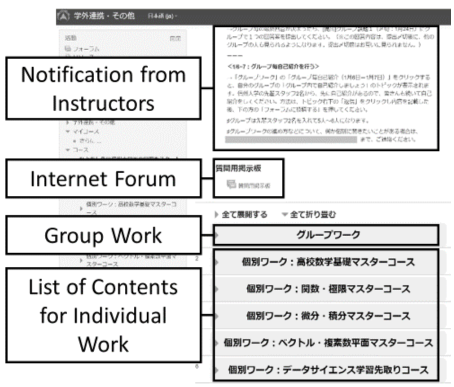


Fig. 1 An eALPS screen where pre-enrollment education is provided.

(Y2), limits of functions (Y3), and limits of number sequences (Y3);
3. Master course in differentials and integrals: differentials and integrals (Y2 and Y3);
4. Master course in vectors and the complex plane: plane figures (Y1), planar vectors (Y2), and complex plane (Y3); and
5. Preliminary course for data science studies: probability (Y1), probability distribution and statistical inference (Y2), and statistical analysis of data (Y2), and university-level materials (Y2 and beyond).

All courses featured final exam problems (15–50 problems) and practice problems (100–300 problems). Applicants who correctly answered all final exam problems (answer submission was allowed multiple times) could download a certificate of completion. Note that the applicants were allowed to directly answer the final exam problems.

3.3 Group Work

In group work, applicants worked on one problem per month. Instructors organized groups based on survey responses during PE enrollment. Each group included 3–4 accepted applicants and 2 SAs. Group membership was fixed until the end of March. Since PE participation was voluntary, applicants could drop out at any time. Group work occurred in six steps:
1. Instructors presented mathematics and statistics problems.
2. Applicants submitted individual answers for problems they worked on individually.
3. Applicants compared their submitted answers and selected a group answer for submission.
4. Each group's representative submitted the group answer.
5. Instructors wrote comments for each group's group answer (describing good aspects and aspects for improvement).
6. All accepted applicants viewed all group answers and instructors' comments.

This PE assigned the following three problems, and groups worked on each problem based on the schedule in **Table 2**:
1. Group work 1: A problem involving finding someone through a binary search (**Fig. 2**),
2. Group work 2: A probability problem in the form of the Monty Hall problem of "deciding which of four doors to choose," and
3. Group work 3: A problem for determining (based on a simple "relationship between two variables" description) the likelihood of a spurious correlation between two samples.

Among the 51 accepted applicants, 34 participated in the PE. According to a survey administered during enrolment, all applicants took high school mathematics III. Considering their self-rated understanding of mathematics I (for handling statistics), A (for handling probability), and III, applicants were organized into seven groups of four and two groups of three, forming nine groups in total. Three accepted applicants dropped out once group work on Problem 1 was completed; at the end of January 2020, there were five groups of four, three groups of three, and one group of two. However, dropouts could return, and so the group assignments remained the same throughout the PE.

Table 2 Schedule for each problem in group work (about one month).

Period	Details
First 3 days	Self-introduction (Problem 1 for group work only): problem explained by an instructor
Following 2 weeks	Individual answer and discussion of the group answer
1 week after answer submission	Viewing of instructors' assessment of the group answer
Final week	Viewing of other groups' answers and instructors' assessment of these

4. PE Results

4.1 Group Work Discussions

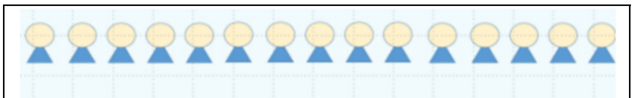
This section describes the group work discussions. Group work Problem 1 had a certain set of relative solutions (Fig. 2). This was the first group work attempt, and so applicants were instructed to work on the problem once they had finished their self-introductions (name, faculty, birthplace, and enjoyable post-university-admission experiences). During self-introductions, applicants mastered the use of eALPS and the working process for group work.

In some groups, certain applicants did not introduce themselves until SAs intervened, and some groups struggled to select applicants to submit the group answer, but most groups submitted their answers before the deadline. All groups provided correct answers. One group described each instance in detail (**Fig. 3**). Another group generalized the number of questions (**Fig. 4**), and yet another group provided vague responses (**Fig. 5**). Thus, the extent of answers differed. Instructors provided feedback on individual answers (Figs. 3 to 5); all the groups' answers and the corresponding feedback were disclosed.

4.2 Assessing Learning-related Self-efficacy

To assess this PE, applicants were asked to respond to a survey after it was concluded. This assessment utilized self-rated understanding (described in Section 3), the level of which was assessed using a four-point scale:
1. 4 points: I can explain the material to others.
2. 3 points: I understand the material.
3. 2 points: I'm somewhat concerned about learning.
4. 1 point: I do not understand the material.

The authors defined a higher level of self-rated understanding (based on the survey) as having high self-efficacy regarding learning. **Table 3** shows the self-rated understanding mean score of five mathematics courses (mathematics I, II, III, A, and B); ap-



Among 15 supposed college students, there is one teacher. Your group must find the teacher by asking them, "Where is the teacher?" (you cannot tell who the teacher is by just looking). When you ask someone, you will receive one of 3 correct responses:
(A) The teacher is me.
(B) The teacher is to the left of me.
(C) The teacher is to the right of me.

Q: You have to find the teacher among the 15 people just by asking the above question 3 times. How should you go about this?

Fig. 2 Problem 1 for group work.

[Group Answer]
Let the person on the far left be Person No. 1 and the person on the far right be Person No. 15. If you ask Person No. 8 and you receive answer (A), Person No. 8 is the teacher.
(1) If Person No. 8 gives answer (B), ask Person No. 4; if you receive answer (A), Person No. 4 is the teacher.
(a) If Person No. 4 gives answer (B), ask Person No. 2; if you receive answer (A), Person No. 2 is the teacher. If you receive answer (B), Person No. 1 is the teacher. If you receive answer (C), Person No. 3 is the teacher.
(b) If Person No. 4 gives answer (C), ask Person No. 6; if you receive answer (A), Person No. 6 is the teacher. If you receive answer (B), Person No. 5 is the teacher. If you receive answer (C), Person No. 7 is the teacher.
(2) If Person No. 8 gives answer (C), ask Person No. 12; if you receive answer (A), Person No. 12 is the teacher.
(c) If Person No. 12 gives answer (B), ask Person No. 10; if you receive answer (A), Person No. 10 is the teacher. If you receive answer (B), Person No. 9 is the teacher. If you receive answer (C), Person No. 11 is the teacher.
(d) If Person No. 12 gives answer (C), ask Person No. 14; if you receive answer (A), Person No. 14 is the teacher. If you receive answer (B), Person No. 13 is the teacher. If you receive answer (C), Person No. 15 is the teacher.
If you ask such questions, you can find the teacher within 3 questions.

[Feedback]
<Positive aspects>
* The conditions are written at the start, and instances are defined based on the response pattern of (A)-(C), which is good.
* The answer was submitted much before the deadline; this was good.
<Aspects needing improvement>
* The conditions only specify people at either end, and so descriptions such as “the person second from the far left is Person No. 2” or “numbering each person, starting at the far left” would indicate the numbers of the people in the middle.

Fig. 3 Answer to group work Problem 1 from a group that described each instance in detail.

[Group Answer]
Line up the people; ask the person in the center of the line. If that person is not the teacher, ask the remaining people to the left (and right). Repeat this process.
That is, line up the 15 people and number them 1-15 starting on the left.
Ask Person No. 8 first. If that person is not the teacher, ask Person No. 4 or No. 12.
Ask Person No. 4, and if that person is not the teacher, ask Person No. 2 or No. 6.
Ask Person No. 12, and if that person is not the teacher, ask Person No. 10 or No. 14.
That is, if you try to find the teacher using this method, 1 question tells you about 3 people, and 2 questions tell you about 7…
n questions allow you to learn about 1 person out of 2^{n+1}-1 people.

[Feedback]
<Positive aspects>
* You provided an answer with specific numbers. Ultimately, you even generalized the relationship between the number of questions and number of data points; this is great.
<Aspects needing improvement>
* You thought about instances, and so you should have identified them by numbers (1), (2), and so on.

Fig. 4 Answer to group work Problem 1 from a group that generalized the number of questions.

[Group Answer]
Ask the person in the center. Eliminate people who answered with a direction. Among the remaining people, ask the person in the center again. If you continue this process, you can find the teacher within 3 questions.

[Feedback]
<Positive aspects>
* You arrived at a simple, general answer.
<Aspects needing improvement>
* Your answer should have included specific numbers.
* Your wording was vague (e.g., “Eliminate people who answered with a direction”), and so write your exact answer.

Fig. 5 Answer to group work Problem 1 from a group that provided vague descriptions.

Table 3 Comparing results of a survey on attended mathematics courses (mean score for self-rated understanding of five mathematics courses).

FY	Classification	N	Mean	SD	p-value
2018	Other than recommended	396	2.97	0.52	1.8×10^{-6} (U)
	Recommended	60	2.61	0.57	
2019	Other than recommended	397	3.00	0.48	7.8×10^{-3} (U)
	Recommended	56	2.80	0.51	
2020	Other than recommended	300	3.01	0.52	1.3×10^{-3} (U)
	Recommended	49	2.76	0.42	
	├ Did not receive PE	27	2.66	0.37	0.063 (U)
	└ Received PE	22	2.89	0.44	
	├Prior to PE	22	2.96	0.49	0.33 (W)
	└After PE	22	2.89	0.44	

(U) p-value according to the Mann-Whitney U test.
(W) p-value according to the Wilcoxon signed-rank test.
SD = standard deviation; PE = pre-enrollment education.

plicants in various classifications were compared. Classifications of “Other than recommended” and “Recommended” were used to categorize students of the faculty of engineering into applicants who passed the examination for recommended candidates and those who did not. Passing applicants were further divided into those who received this PE up to March 2020 and those who did not. Scores of individuals who received PE were compared between pre-PE (based on the survey conducted during enrollment; see Section 3.1) and post-university admission situations.

For statistical comparison, this study used the (a) Mann-Whitney U test and (b) Wilcoxon signed-rank test. Depending on the distributions' normality and equivariance, it was necessary to conduct Welch's t-test, for example. However, one report [16] suggested that normality tests should be used only as a reference, and this research followed this finding. Since the F-test results showed that the variances were not different, tests (a) and (b) were conducted in this research.

A statistically significant difference was not noted; however, Table 3 indicates that individuals who received PE had higher mean scores than individuals who did not receive PE or who passed the 2018 or 2019 recommended candidate examinations. However, no major score changes were detected before or after PE application. Thus, although we cannot claim that self-efficacy improved, it may have been maintained.

4.3 Assessing the Alleviation of Pre-admission Concerns

The previous section's survey asked applicants to answer questions (see **Table 4**) using the following five-point scale:

1. 5 points: I really agree.
2. 4 points: If I had to decide, I would say I agree.
3. 3 points: I cannot say.
4. 2 points: If I had to decide, I would say I disagree.
5. 1 point: I really disagree.

Table 4, which shows the number of responses to each question based on the point scale, indicates that most responses were positive (e.g., “I am glad I participated in this PE” and “I would recommend PE participation to students admitted next year.”) There-

Table 4 Post-pre-enrollment education (PE) survey responses (no. of responses).

Questions	5	4	3	2	1
System operation (logging in, submitting comments, and so on) was simple.	3	6	0	7	0
I am glad I participated in this PE.	11	4	1	0	0
My post-admission concerns disappeared thanks to this PE.	1	2	3	3	7
I would recommend PE participation to students admitted next year.	7	6	2	1	0

fore, applicants viewed this PE favorably; furthermore, "satisfaction" (ARCS model) effects were observed, as shown in Table 1. However, there were numerous negative responses regarding concern alleviation. COVID-19-related post-admission concerns may have influenced the survey responses because this survey was conducted just before the declaration of a state of emergency in Japan.

5. Conclusion

This study overviewed the implementation and results of a perfectly asynchronously distributed PE. The results revealed that accepted applicants may be able to maintain their self-efficacy post-PE. Accepted applicants who received this PE viewed it favorably. Initially, this PE was not devised as a measure for dealing with COVID-19, but this study's results indicated that effective PE to maintain self-efficacy could be provided even under such difficult circumstances. In the future, we will identify PE-related effects and issues by qualitatively analyzing interactions between accepted applicants during group work and by conducting ARCS model-based evaluations.

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