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 Esalminejad [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.
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.

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

Figure 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.

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

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^{-4} (U) |
|          | Recommended             | 60 | 2.61 | 0.57 |         |
| 2019     | Other than recommended  | 397| 3.00 | 0.48 | 7.8×10^{-4} (U) |
|          | Recommended             | 56 | 2.80 | 0.51 |         |
| 2020     | Did not receive PE      | 27 | 2.66 | 0.37 | 0.063 (U) |
|          | Prior to PE             | 22 | 2.89 | 0.44 |         |
|          | After PE                | 22 | 2.89 | 0.44 | 0.33 (W) |

(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.

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

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

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.”)
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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References

[1] Hirai, Y., Tokita, M., Takano, K., et al.: Pre-University Education for Students Passed the Early Entrance Examination in the Faculty of Engineering, Proc. 2019 Joint Forum of UeLA & JADE (in Japanese), pp.34–38 (Mar. 2020).

[2] Hirai, Y., Tokita, M., Takano, K., et al.: Results of Pre-University Education for Students Passed the Early Entrance Examination in the Faculty of Engineering, Proc. 45th Annual Conference of JSiSE (in Japanese) (Sep. 2020).

[3] Uesato, T., Seki, Y., Kimura, H. and Takeuchi, S.: Pre-enrollment Education Named ‘Kochi University Pre-University Moodle’ via Internet: An Attempt to Keep Learning Motivation, Journal for Research on University Entrance Examinations (in Japanese), Vol.29, pp.29–35 (Mar. 2019).

[4] Oh, H.-S.: Influence of Learning Motivation, Communication Skill, Academic Self-Efficacy on Self-Directed Learning Ability in Nursing Students, Journal of Digital Convergence, Vol.15, No.8, pp.311–321 (Aug. 2017).

[5] Saeid, N. and Eslaminejad, T.: Relationship between Student’s Self-Directed-Learning Readiness and Academic Self-Efficacy and Achievement Motivation in Students, International Education Studies, Vol.10, No.1, pp.225–232 (Dec. 2016).

[6] The Japan Association of Private Universities and Colleges (JAPUC): Special Issue: Current State and Challenges on Pre-enrollment Education, University Current Review (in Japanese), Vol.384, pp.34–72 (Jan. 2019).

[7] Du, J., Fan, X., Xu, J., et al.: Predictors for Students’ Self-Efficacy in Online Collaborative Groupwork, Educational Technology Research and Development, Vol.67, No.4, pp.767–791 (Aug. 2019).

[8] Keller J.M.: Motivational Design for Learning and Performance: The ARCS Model Approach, Springer (May 2015).

[9] Hodges, C.B. and Kim, C.: Improving College Students’ Attitudes toward Mathematics, TechTrends, Vol.57, No.4, pp.59–66 (May 2013).

[10] University E-Learning Association, available from (https://uela.jp) (accessed 2020-08-01).

[11] Japan Agency for Medical Research and Development (AMED), How to Choose a Statistical Test - Tests Can Change Conclusions! De-liberately Choosing an Inappropriate Test is Cheating, available from (https://www.amed.go.jp/content/000034160.pdf) (accessed 2021-03-27).

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