Comparing Synchronous and Asynchronous Online Programming Classes: Similarities and Differences

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***Abstract*—With the temporary transition from offline classes to online education due to the COVID-19 pandemic, students' dissatisfaction has grown as face-to-face interactions have been disrupted. This paper conducts research on the delivery methods of online courses, with a focus on computer programming courses, to provide insights into the design of online courses. The study compares two groups, divided into synchronous and asynchronous delivery, in terms of academic achievement, perception of the delivery method, software attitudes, and satisfaction related to course objectives. Academic achievement utilized data from students' final grades. In addition, perception, attitude, and satisfaction were surveyed at the beginning and end of the semester using self-reported questionnaires. The analysis results showed that only the perception of the delivery method was statistically significant on average. The purpose of this research is to provide insights for the design of online courses. It is hoped that the findings of this study will be beneficial in making decisions regarding online course design.**

***Keywords*—software education, online class delivery method, software attitude, class satisfaction**

I. Introduction

With the outbreak of COVID-19 in 2019, most schools closed their doors or transitioned to online education, leading students to face difficulties as a result of the sudden shift to online classes. During this period, students were required to move residences abruptly in the middle of the semester, and they had to attend classes from their homes during lockdown periods [1]. Internet and computer access were sometimes limited or unavailable, and, in some cases, there were even issues with unstable power supply. The economic repercussions of COVID-19 also led to job losses [1, 2]. Some students had to balance the responsibility of caring for their children or family members while attending classes online [1].

Students encountered difficulties not only with the online tools used for classes but also due to an excessive workload that hindered effective learning. Additionally, communication issues with instructors made it difficult to correct misconceptions or address questions about the course material. Problems with communication with peers who were also taking the same class made group activities challenging, and the domestic responsibilities hindered their ability to fully concentrate on their studies. Prolonged online learning sometimes resulted in eye strain, headaches, and difficulties associated with extended periods of focus. As social isolation continued, feelings of depression and anxiety increased, and self-esteem and quality of life declined [2].

According to a satisfaction survey conducted on university students regarding online classes, 40.5% expressed dissatisfaction. Limited internet access, low instructor attachment, and guidance were identified as the causes of this dissatisfaction [3]. Similarly, 78% of students expressed dissatisfaction with the Zoom system for online classes [4]. In South Korea, non-face-to-face education has been in place for a long time, and students have raised complaints about not achieving the lecture quality comparable to traditional offline classes, leading to demands for tuition refunds [5].

On the other hand, Software (SW) subjects pose a challenging issue for most students, and this problem has been a subject of interest for computer science education researchers for over 40 years [6]. Computer programming courses generally have a high dropout rate [7]. This is because students need to grasp programming language syntax, apply semantic rules, and demonstrate problem-solving skills in case of programming errors, making it difficult to continue learning without strong motivation [8, 9]. Additionally, according to Kirsh and Gaber [10], a key factor among successful students in computer programming courses is a substantial time investment.

Settle [11] compared student satisfaction after conducting a Java programming course using two methods: online classes and traditional classes. The results showed that students found online classes to be less systematic and believed that course objectives were not being achieved. Furthermore, the satisfaction results regarding instructor-related questions in surveys were much lower for online classes compared to traditional offline classes. The authors suggested that the lack of communication between instructors and students and among students may have influenced the satisfaction ratings.

According to Swan [12], online classes receive relatively more stringent evaluations from students compared to traditional classrooms due to the limited interaction with instructors. This makes students assess the online learning structure more critically, rendering online class evaluations more challenging compared to traditional classrooms.

Despite existing research, there remains a shortage of studies on the delivery methods of online classes. Particularly, there has been minimal research on computer programming courses, which require a substantial amount of practice and interaction between students and instructors. Clary *et al.* [13] reported that there is still a demand for remote classes in the post-pandemic era, and in South Korea, even traditional universities are offering online degree programs, with 20 universities having established them [14]. Therefore, there is still a need for research on online classes. As previously mentioned, online environment courses demand higher

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motivation compared to traditional learning, making it necessary to research online computer programming courses to ensure their success at this point.

In this study, we compared synchronous and asynchronous approaches to increase satisfaction in online computer programming classes. Given the potential for different outcomes based on the learning environment [15], real-time Zoom lectures offer more open communication between instructors and students compared to pre-recorded lectures [16], necessitating an examination of how Swan's [12] research results apply in the COVID-19 era of online learning.

This paper conducted a comparative study by dividing non-Computer Science (non-CS) major students into two groups: real-time Zoom lectures and pre-recorded lectures for an online computer programming course. Surveys were conducted at the beginning and end of the semester, allowing for cross-sectional analysis of each method and a comparison of their final grades.

The objectives of this paper are as follows:

1) To investigate whether there are differences in academic achievement among students based on the method used to conduct online computer programming courses for non-CS major students.
2) To determine if there are differences in students' perceptions of the delivery method of online computer programming courses for non-CS major students.

This study aims to fill the research gap regarding differences in academic achievement and perception based on the online learning format for students taking online computer programming courses.

To achieve this, the following hypotheses are formulated and tested in the research:

H_0: There is a difference in academic achievement among non-CS major students based on the method used to conduct online computer programming courses.

H_1: There is a difference in students' perception of the delivery method of online computer programming courses among non-CS major students.

H_2: There is a difference in students' software attitudes based on the method used to conduct online computer programming courses among non-CS major students.

H_3: There is a difference in student satisfaction based on the method used to conduct online computer programming courses among non-CS major students.

The structure of this paper is as follows: Section II covers the research background, Section III introduces the research model, Section IV verifies the hypotheses through statistical analysis, and Section V discusses and concludes the study.

This study provides insights into the delivery methods of online programming courses and is expected to serve as fundamental material for effectively conducting software education.

II. Research Background

A. Perceptions of Online Class Delivery Methods

The rapid transition to online education worldwide due to the COVID-19 pandemic brought significant changes to the education landscape. According to Beller and Or [17] and Kiser [18], education has struggled to adapt to the changes brought about by the internet. As of 2019, the proportion of online classes in domestic universities remains at only 1% of the total courses [19]. Consequently, the abrupt shift from traditional classrooms to online education has posed challenges for both instructors and students. Students are willing to participate in online classes but still tend to prefer face-to-face classes [20, 21]. This preference may arise because in online settings, students cannot easily seek help from peers, access libraries, or use laboratories [22]. Furthermore, students often exhibit a passive tendency and may not want their faces visible during online classes [23, 24]. As the semester progresses, they tend to perceive online learning as more challenging [25]. Online classes are broadly categorized into synchronous (real-time) and asynchronous (pre-recorded lectures) modes [26].

1) Synchronous online class delivery

Synchronous online classes mean that the location of the class can be chosen by students, but the class is conducted at a predetermined time for everyone [27]. Tools such as Microsoft Teams, Google Meets, and Zoom can be utilized for this mode [28].

Gazan [29] conducted interviews with 24 students and summarized the advantages and disadvantages of synchronous classes as follows:

Advantages include the ability to participate in classes from any desired location without the need to travel to a physical classroom and the option to ask questions at any time using features like a hand-raise button when any doubts arise.

Disadvantages include the requirement for students to have the necessary equipment such as a personal computer and an internet connection to attend classes. Quality issues with these devices may lead to disruptions during classes. Additionally, there can be vulnerabilities related to security. However, in contrast, according to Barr [24], students tend to be less proactive in asking questions during live classes.

2) Asynchronous online class delivery

Asynchronous online classes allow students to choose both the location and time for their classes [30]. Classes may be conducted through pre-recorded videos or other accessible materials available online [29].

Gazan [29] reported the advantages and disadvantages of asynchronous classes as follows:

Advantages include the freedom for learners to decide both the location and time of their classes. Furthermore, students can repeat the classes multiple times to ensure a full understanding of the content before attempting assignments.

Disadvantages are related to communication issues. Since class attendance times can vary among students, there may be uncertainty about when fellow students will respond to chat messages. Students also expressed that they could be more interactive if classes were conducted in real-time. Additionally, learners indicated that they would prefer a combination of synchronous and asynchronous methods if offered.

Based on prior research, interactions between instructors and students are known to impact students' academic achievement [31, 32], students' perceptions of the learning environment [33], and their self-esteem [34]. Considering these findings, H_0 and H_1 were proposed.

In this study, online class perception was defined as the learners' subjective views and beliefs regarding the delivery methods of online classes. Arbaugh [35] and Piccoli *et al.* [36] designed PER1, PER2, PER3, PER4 as shown in Table 1. Since the primary concern was the impact of online class delivery methods on satisfaction, each study included several questions related to usefulness, ease of use, and design aspects. Additionally, as the entire learning environment in online classes is digital, it was assumed that digital device utilization skills would improve during this process [37]. Therefore, PER5 was added, as shown in Table 1.

Table 1. The online class perception questionnaire

Item	Questions
PER1	The course delivery method is suitable for learning software theory.
PER2	The course delivery method is suitable for practical programming.
PER3	The course delivery method enhances understanding of lecture content.
PER4	The course delivery method aids in maintaining the ability to read and write source code.
PER5	The course delivery method contributes to the improvement of digital device usage skills.

B. *Software Attitude*

Previous research on computer attitudes [38, 39] and computer anxiety [40] has been conducted since the advent of computers. Computer anxiety primarily involves negative emotional reactions that occur when using or contemplating the use of computers. Computer attitude, on the other hand, refers to one's disposition toward computers, whether they like, find them useful, or consider them easy to use [39]. Such attitudes are a significant factor in determining computer usage [41]. Many studies on computer attitudes have been conducted since the appearance of personal computers in the 1980s. Gardner *et al.* [39] viewed computers as a masculine domain for measuring computer attitudes, encompassing computer anxiety, computer liking, impact of computers on society, computer appreciation, computer confidence, computers as useful, motivation to succeed using computers, and computer attitude.

Adem and Senturk [42] compared a blended learning environment with traditional teaching in a computer applications course and found significant differences in students' computer attitudes between the two methods. Blended learning resulted in positive outcomes in both academic achievement and computer attitude. Hence, different results were obtained based on the delivery method.

However, the concept of computer attitude as it was initially studied is no longer appropriate in the present day when it is common for individuals, even non-experts, to use computers for complex tasks [43]. Therefore, it is essential to examine attitudes toward Software (SW) in more detail than computer attitudes in today's era of the Fourth Industrial Revolution. In this study, software attitude is defined as the attitude toward software, including liking, finding it useful, and considering it important. The aim was to examine whether students' software attitudes change after one semester, requiring a reinterpretation of the content of previous studies related to computer attitudes as software attitudes. In Gardner *et al.*'s [39] research, the term "computers" was replaced with "software" in reference to survey items related to computer liking, the social impact of computers, computer appreciation, computer usefulness, and so on. Based on the results of Adem and Senturk's [42] study, this led to the formation of Hypothesis 2, stating that the delivery method affects students' software attitudes.

The survey items used in the self-report questionnaire in this study were extracted from the 'Thoughts on Software' survey items from the Korea Educational and Research Information Service's 'SW Education Research School Effectiveness Analysis Study' [44]. Therefore, the items used in the self-report questionnaire for this study are presented in Table 2.

Table 2. The software attitude questionnaire

Item	Questions
ATT1	Software enhances the convenience in our daily lives.
ATT2	There is a demand for jobs related to software after graduation.
ATT3	Software plays a vital role in the development of our society.
ATT4	Learning software is a crucial subject in our educational curriculum.
ATT5	The number of software learning hours at school should be increased.
ATT6	Software knowledge will become a requirement for most future job opportunities.

C. *Course Satisfaction*

Course satisfaction is an important topic in previous research. From the perspective of viewing students as consumers, satisfaction is a significant issue in online learning research [45]. Students have the right to evaluate the course [46]. Satisfaction is a kind of internal emotional response that learners feel during the learning process [47]. If learning activities meet or exceed learners' expectations, they are considered "satisfied"; otherwise, they are deemed "dissatisfied." Satisfaction affects the ongoing learning activities [46] and time investment [48, 49]. Additionally, learners' satisfaction can influence their learning motivation [50]. Hew *et al.* [51] identified factors affecting MOOC course satisfaction as course instructors, course content, assessment, and course schedules.

Effective course planning for online courses can be an excellent starting point to help students explore and engage in online learning [52]. A syllabus includes course goals and objectives, assignment information, course schedules, and evaluation methods, among other things [53]. Students can review their course syllabus to set achievable learning goals. Ultimately, students express greater satisfaction with online courses when they feel that their goals have been achieved [46].

Programming-related knowledge is becoming increasingly important in the new job market [54]. Therefore, computer programming courses need to be well-designed. Additionally, the evaluation of student reactions to programming courses is essential for the reasons mentioned earlier. In this study, we focus primarily on the content related to learning goals based on the importance of course objectives and their achievement, as discussed by Settle [11] and Denson *et al.* [55]. The course we are conducting is a computer programming course, an elective subject with the main goals of enhancing computational thinking, improving understanding of software, and cultivating Science, Technology, Engineering, Art, Mathematics (STEAM) literacy or interdisciplinary knowledge. Since goal achievement is a significant factor influencing student course satisfaction [46], this study constructs the survey questionnaire focusing on content related to learning goals. Furthermore, course satisfaction can vary based on the method of online course delivery [56, 57]. Hence, we propose Hypothesis 3.

The course satisfaction items used in the survey for this study are as presented in Table 3.

Table 3. The course satisfaction questionnaire

Item	Questions
SAT1	This course enhances computational thinking skills.
SAT2	This course increases understanding of software.
SAT3	This course cultivates STEAM literacy.

III. Research Model

A. Research Procedure

This study followed a specific procedure outlined as follows. The initial step involved conducting a thorough literature review to inform the development of the questionnaire. Subsequently, a pre-survey was administered. Following a semester of the course, a post-survey was conducted. The post-survey incorporated questions that could only be answered by students who had completed the course, thereby allowing for a comparison with the pre-survey responses.

For data analysis, the statistical software SPSS v.27 (IBM Korea, Seoul, Korea) was utilized. The analysis process can be outlined as follows:

First, an independent sample t-test was employed to investigate potential significant differences in academic achievement associated with the online class delivery method.

Second, the average scores for questionnaire items were compared with regard to both the time point (pre-survey and post-survey) and the online class delivery method, as illustrated in Fig. 1. Analyzing these distinctions involved the utilization of independent sample t-tests for comparing online class methods, and paired-sample t-tests for each time point.

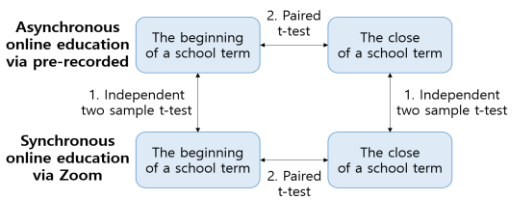

Fig. 1. The comparison between questionnaire completion time and online class delivery method.

B. Study Participants

This study targeted non-CS major students who enrolled in Python programming courses during the second semester of 2021, spanning 15 weeks. Two course delivery methods were offered:

Pre-recorded Lectures: In this mode, students had access to video lectures which they could watch at their own pace within a specified period.

Live Zoom Lectures: These lectures occurred at scheduled times and days through Zoom meetings. Attendance was recorded in the Zoom session. Due to institutional policies, Zoom recorded videos were not available for this format.

Both course formats covered the same content, which included learning Python syntax and practical exercises involving web scraping and application programming interfaces, building upon a basic understanding of web concepts. The course places a strong emphasis on practical exercises, with weekly assignments assigned. Following the submission of assignments by the students, the instructors and teaching assistants provided feedback on all submitted assignments.

The grading criteria for both classes included 15% for attendance, 10% for homework, 35% for the midterm exam, and 40% for the final exam. Students were encouraged to seek clarification by visiting the instructor at any time or by asking questions through various channels such as email, LMS messaging, or Kakao Talk open chat.

In the case of pre-recorded lectures, students did not have the opportunity to see the instructor's face. However, for live Zoom lectures, students had the advantage of observing the instructor's facial expressions and teaching style. Students often opted not to turn on their cameras during live Zoom sessions. They utilized real-time chat for posing questions rather than using their microphones.

The pre-recorded lectures had 76 attendees, with one student absent, while the live Zoom lectures had 58 participants. The survey was administered twice during the course, at weeks 2 and 15. A total of 58 students from the pre-recorded lectures and 53 from the live Zoom lectures participated in both surveys. Prior to the survey, all students were informed about the study's purpose and the guarantee of privacy, and their participation was voluntary. The survey employed a 5-point scale, ranging from "not at all" to "very much," to collect responses from the students. Furthermore, students were asked to provide feedback on the strengths and weaknesses of each method.

IV. Experiment and Result

A. Step 1: Academic Achievement Comparison

Prior to conducting the analysis, we calculated the minimum sample size using the G*Power program. The total number of students who received grades was 134. Considering a two-tailed test, a power of 0.8, and an allocation ratio of 1, the minimum sample size of 128 was achieved, allowing for the subsequent analysis.

Furthermore, the internal consistency reliability of the questionnaire items in Section II was assessed. The results can be found in the Table A1. Upon measuring Cronbach's alpha coefficients, online class perception showed 0.897, SW attitude displayed 0.709, and course satisfaction indicated 0.894. Even when specific items were removed, the alpha values for all factors remained above 0.6, demonstrating relatively high item reliability.

Table 4 displays the results of t-tests comparing the grades between the two groups. The grade comparison was calculated based on the entire student population (total of 134 students, pre-recorded: 76, Zoom: 58). Based on the results of Levene's test, if the test is non-significant ($p > 0.05$), equal variances are assumed; otherwise ($p < 0.05$), unequal variances are assumed between the groups, and the appropriate p-value is selected for the independent samples t-test.

Table 4. Comparison of score results

Type	(Number of students) Mean			t	Sig. (2-tailed)
	Pre-recorded	Comparison	Zoom		
Overall score	(76) 76.7	<	(58) 78.8	−0.763	0.502
Above the 50th percentile	(38) 90.6	>	(29) 90.3	0.266	0.791
Below the 50th percentile	(38) 62.8	<	(29) 67.3	−1.068	0.289

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$, ****$p < 0.001$

First, the average score for pre-recorded lectures was 76.7, and for live Zoom lectures, it was 78.8, which was slightly higher. The absolute value of the test statistic t was 0.763, and the p-value exceeded 0.05, indicating no statistical significance.

Second, the results pertain to students above the 50th percentile only. The average score for pre-recorded lectures was 90.6, while for live Zoom lectures, it was 90.3. Although the pre-recorded lectures had a slightly higher average, the difference was negligible. The test statistic t value was 0.266, which was less than 1.96, and the p-value exceeded 0.05, indicating no statistical significance.

Third, the results for students below the 50th percentile are as follows: the average score for pre-recorded lectures was 62.8, and for live Zoom, it was 67.3, which was higher. The test statistic and p-value indicated no statistical significance, as the p-value exceeded 0.05.

In summary, after comparing the grades of the two groups, we reject the hypothesis H_0.

B. Step 2: Comparison of Students' Perceptions, Software Attitude and Course Satisfaction

To conduct the analysis, we first determined the minimum sample size. The total of students who took the two surveys was 111. However, the available sample size was only 128 calculated by G*Power program, falling short of the required minimum by 17 participants (128–111). While the sample size exceeded 30, the insufficiency of the minimum sample size raised concerns about potential bias. As a result, we conducted an additional non-parametric test, the Mann-Whitney U test.

Table 5 displays the results of both the independent sample t-test and the Mann-Whitney U test for pre-recorded lectures and live Zoom lectures conducted at the beginning and end of the semester. In this table, the p-value for the independent sample t-test was determined following Levene's equal variance test, consistent with the approach used in the previous comparison of students' scores.

Table 5. Comparison of online class delivery methods

The comparison between the online class method	Week 2				Week 15			
	Pre-recorded	Comparison	Zoom	Sig. (M-W U test)	Pre-recorded	Comparison	Zoom	Sig. (M-W U test)
ATT1	4.62	>	4.58	0.74556 (0.644)	4.60	<	4.68	0.485625 (0.794)
ATT2	2.90	>	2.85	0.79067 (0.866)	2.90	<	2.98	0.646925 (0.647)
ATT3	4.66	<	4.72	0.52132 (0.672)	4.71	<	4.75	0.591515 (0.679)
ATT4	4.38	<	4.47	0.52338 (0.732)	4.47	>	4.36	0.419346 (0.196)
ATT5	3.79	>	3.75	0.81771 (0.568)	3.90	>	3.75	0.411095 (0.326)
ATT6	4.40	>	4.23	0.16707 (0.127)	4.41	>	4.38	0.786825 (0.591)
SAT1	4.39655	>	4.396226	0.99786 (0.848)	4.43	<	4.60	0.185442 (0.612)
SAT2	4.41	>	4.40	0.88291 (0.894)	4.48	<	4.51	0.854676 (0.356)
SAT3	4.33	>	4.19	0.296311 (0.358)	4.31	<	4.45	0.363341 (0.779)
PER1					4.21	>	3.68	0.006962*** (0.002***)
PER2					4.14	>	3.43	0.000883**** (0.001***)
PER3					4.19	>	3.51	0.000146**** (0.000078****)
PER4					4.05	>	3.72	0.062641* (0.052*)
PER5					4.17	>	3.70	0.008811*** (0.007***)

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$, ****$p < 0.001$

At the beginning of the semester, since no classes had been conducted, we did not administer a survey regarding the online class delivery method. Consequently, the p-values of the surveys related to SW attitude and course satisfaction, conducted at the beginning and end of the semester, according to the delivery method of the two online lectures were found to be statistically insignificant, with values equal to or greater than 0.05. Thus, H_2 and H_3 were rejected.

At the end of the semester, five additional questions, focusing on theoretical compatibility (PER1), practical suitability (PER2), content comprehension (PER3), digital device utilization ability (PER5), and programming performance significance (PER4), were included. Furthermore, both pre- and post-surveys were conducted anonymously; therefore, a question in the post-survey inquired about whether participants had completed the pre-survey. For four out of these five questions, the mean ratings for the pre-recorded lectures were higher than for the live Zoom lectures, and the *p*-value was less than 0.05, indicating statistical significance. The programming performance significance probability (PER4) was 0.062, statistically significant at the 0.1 level. In other words, it can be concluded that the students' average perceptions of the five questions on the online class methods were not the same. Therefore, H_1 is accepted.

Second, prior to conducting paired-sample t-test analysis, the minimum sample size was calculated using the G*Power program. By following the same criteria, the minimum sample size (34) was met, and the analysis was subsequently carried out.

Table 6 displays the results of the t-test conducted between the beginning and the end of the semester in relation to online lectures. Upon conducting a comparative analysis of SW attitude and course satisfaction for the pre-recorded lectures and SW attitude for the live Zoom lectures at the beginning and end of the semester, it was determined to be statistically insignificant. However, in the case of the live Zoom lectures, two specific items, namely, the enhancement of computational thinking (SAT1) and the improvement in STEAM literacy (SAT3), exhibited t-values exceeding the absolute value of 1.96, indicating statistical significance. Furthermore, the survey questions pertaining to course satisfaction for the live Zoom lectures demonstrated an increase from the beginning to the end of the semester.

Table 6. Comparison of questionnaire completion time

Variable	Pre-recorded				Zoom			
	Week 2	Comparison	Week 15	Sig. (2-tailed)	Week 2	Comparison	Week 15	Sig. (2-tailed)
ATT1	4.62	>	4.60	0.820824	4.58	<	4.68	0.321941
ATT2	2.90	=	2.90	1.000000	2.85	<	2.98	0.211754
ATT3	4.66	<	4.71	0.443366	4.72	<	4.75	0.597756
ATT4	4.38	<	4.47	0.357652	4.47	>	4.36	0.203758
ATT5	3.79	<	3.90	0.359040	3.75	=	3.75	1.000000
ATT6	4.40	<	4.41	0.849325	4.23	<	4.38	0.102972
SAT1	4.40	<	4.43	0.765925	4.40	<	4.60	0.010234**
SAT2	4.41	<	4.48	0.551093	4.40	<	4.51	0.277454
SAT3	4.33	>	4.31	0.890067	4.19	<	4.45	0.037740**

*p<0.1, **p<0.05, ***p<0.01, ****p<0.001

V. DISCUSSION

The discussion of our study is presented as follows.

First, our rejection of the hypothesis H_0 implies that there is no significant difference in students' academic achievement between the two delivery methods. We conducted an independent-samples t-test on students' grades, dividing them into those above the 50th percentile and those below the 50th percentile of overall grades. The results revealed no statistically significant difference in means. However, upon closer examination, a noteworthy distinction emerged. Students above the 50th percentile showed a minimal difference of 0.307% in academic achievement, while those below the 50th percentile exhibited a more substantial decrease of 4.481%, equating to a percentage difference of 6.89%. This observation aligns with a study conducted by Le [58], which found that pre-recorded lectures tend to negatively impact the academic achievement of lower-ability students, whereas no discernible effect is observed among higher-ability students. In light of this, it becomes imperative to formulate strategies aimed at preventing lower-ability students from falling behind in the context of pre-recorded lectures.

Second, our acceptance of the hypothesis (H_1) signifies that there is indeed a difference in students' perceptions based on the delivery methods. After the course commenced, we conducted surveys on five questionnaire items: SW theory learning (PER1), programming practice (PER2), understanding of class contents (PER3), reading and writing of source code (PER4), and improving ability to use digital devices (PER5). Towards the end of the semester, we performed independent samples t-tests and Mann-Whitney U tests. Across all items, the mean scores for live Zoom lectures ranged around 3, while those for pre-recorded lectures consistently averaged around 4, indicating that students generally favored pre-recorded lectures. Statistically significant differences were observed for all items except reading and writing of source code ($p < 0.1$), with p-values less than 0.05. The most substantial percentage differences were evident in programming practice (18.758%) and understanding of class content (17.662%). Consequently, it is evident that students exhibit a relative preference for pre-recorded lectures in the context of computer programming courses. Student feedback further substantiates this preference. For pre-recorded lectures, students expressed sentiments such as, "Learning the course content while actively executing code using the pause button was highly beneficial." On the other hand, concerning live Zoom lectures, students raised concerns like "Managing Zoom, Python Idle, and an internet browser simultaneously is inconvenient," "Typing is slow, making it difficult to catch up if there's a delay," and "Directly asking questions on Zoom is a challenge." Particularly in the real-time lecture and practice setting, students appear to encounter obstacles when seeking clarification or help. This aligns with the findings of

Barr *et al.*'s study [24], which observed that the absence of visual cues, especially when students collectively opt not to activate their webcam videos, results in students "suffering in silence" and hesitating to seek assistance in front of the entire class.

Third, our analysis of hypothesis H_2 revealed that there is no significant difference in SW attitude based on the delivery methods. Both the independent sample t-test and Mann-Whitney U test results from surveys conducted at the beginning and end of the semester showed no statistically significant distinctions. This suggests that students from both groups, who were primarily non-CS majors, share a common positive attitude toward software. The sentiments expressed by students further substantiate this positive disposition. For instance, a student from the pre-recorded lectures stated, "I enrolled in this course with the aim of acquiring the competence to gather data using Python. Although it was a short period, I am pleased that I gained valuable knowledge on web scraping, which will greatly assist in collecting public data and news articles." Similarly, a student from the live Zoom lectures expressed, "The course on web scraping was informative, and I believe it will be highly useful for data collection and processing in the future." Notably, both delivery methods yielded similar negative responses with a mean score of 2 in the questionnaire item pertaining to SW occupation (ATT2). This suggests that the courses were general electives, not specialized subjects, which may explain this pattern.

Fourth, we found that hypothesis H_3, positing a difference in course satisfaction based on delivery methods, was not supported. Insights from students' feedback revealed that both groups acknowledged the fulfillment of course objectives. A student from the pre-recorded lectures commented, "As a liberal arts student who was not well-versed in computers, I gained a basic understanding of software and now wish to delve further into it." Similarly, a student from the live Zoom lectures stated, "I am a liberal arts major, and I believe I would not have acquired knowledge of software if it weren't for this course." Nevertheless, when examining the results of the paired-sample t-test, we observed statistical significance in two items related to live Zoom lectures: improvement in computational thinking ability (SAT1) and STEAM literacy (SAT3). More specifically, we noted a 4.44% difference in computational thinking ability improvement for live Zoom lectures compared to a mere 0.68% difference for pre-recorded lectures. Although the increase in SW comprehension (SAT2) was not statistically significant for both methods, the percentages demonstrated growth for pre-recorded lectures (1.575%) and live Zoom lectures (2.469%). Notably, there was a substantial increase of 6.019% in STEAM literacy improvement (SAT3) for live Zoom lectures, while STEAM literacy improvement for pre-recorded lectures exhibited a negligible absolute difference of 0.02, signifying minimal change. Based on these results, it is believed that live Zoom lectures have a more significant impact on course satisfaction, measured in terms of improved computational thinking skills, increased understanding of SW and cultivation of STEAM literacy than pre-recorded lectures.

VI. Conclusion

While research related to delivery methods has been conducted in light of COVID-19, there is a lack of studies analyzing online class delivery methods for programming courses, where practical exercises hold relatively higher importance. Therefore, this study holds significance in comparing and analyzing students' performance, perceptions of online classes, software attitudes, and course satisfaction between synchronous and asynchronous delivery methods. Furthermore, our analysis results pave the way for potential follow-up studies, allowing for investigations into the following areas based on our findings.

First, considering that students value communication, online courses should be designed and conducted with this in mind. With this view, online classes should preferably be conducted in real-time. If prerecorded classes are unavoidable, a hybrid approach that combines synchronous and asynchronous elements, allowing students to engage in communication and learning, should be adopted, instead of delivering the entire course asynchronously. Thus, online teaching demands more preparation and case studies than offline teaching. In this process, not only quantitative research but also qualitative research, involving the opinions of both instructors and students, is required.

Secondly, when conducting online classes, it is necessary to provide students with course guidelines to enhance their perceptions of online classes. Although learners who took pre-recorded lectures gave higher scores in terms of their perception of online classes, real-time Zoom classes yielded better results in terms of course satisfaction. In other words, there is a difference between preference and actual response evaluation. Therefore, it is essential to inform students at the beginning of the semester about the advantages of each online class delivery method and how to maximize their learning effectiveness. Developing and implementing the suggested instructional models for each online class delivery method, as described above, can significantly contribute to improving perceptions of online classes.

There are several limitations to this study. Firstly, the data were collected solely in Korea, which may limit the generalizability of the findings to other cultural contexts. Additionally, due to the insufficient sample size of student data collected, a non-parametric method was employed for the comparative analysis of online class perception, SW attitude, and course satisfaction. Therefore, further research in diverse regions is needed.

Appendix

Table A1. Test result for internal consistency reliability

Testing for reliability	Cronbach's alpha	Questions	Cronbach's alpha if the item was deleted
Online class perception	0.879	PER1	0.862
		PER2	0.856
		PER3	0.836
		PER4	0.860
		PER5	0.854
SW attitude	0.709	ATT1	0.731
		ATT2	0.707
		ATT3	0.702
		ATT4	0.605
		ATT5	0.632
		ATT6	0.610
Course satisfaction	0.894	SAT1	0.833
		SAT2	0.820
		SAT3	0.897

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

H. Ha, and S. Yoo developed the idea of research. S. Yoo prepared the theoretical base of research and H. Ha conducted a survey and statistical analysis of data. All authors had approved the final version.

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