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Learning Performances towards the BookRoll E-Book System for Flipped Classrooms in Software Engineering Education

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ABSTRACT: The aim of software engineering education is to educate students in software technologies, developments, procedures, and scientific practices to enable them to cope with industrial demands. However, the implementation of software engineering education in traditional university classrooms is restricted by the semester structure, making it difficult to achieve a proper learning balance between theory and practice. To balance theoretical and practical learning, prior studies have indicated that flipped learning is a suitable classroom setting for students and teachers. In a flipped learning environment, it is important to enhance and capture students' learning performance before the class to facilitate teachers and students in proceeding with in-class instruction and learning. In this study, an e-book system named BookRoll was applied to support software engineering education in a flipped learning setting. The proposed approach supports and facilitates out-of-class and in-class learning by providing reading and learning analytic functions for teachers and students. To evaluate the proposed approach, two classes of students were allocated to an experimental group and a control group to participate in an experiment. In the flipped learning process, the experimental group was supported by the BookRoll system, while the control group did not use the BookRoll system. The results revealed that the proposed approach not only promoted students' learning achievements in software engineering education but also improved their learning motivation, attitude, and problem-solving ability. The reading behavior analysis further indicated that reading time was a statistically significant predictor of learning achievement.

Keywords: Flipped classroom, Software engineering education, E-book system, Reading behaviors, Quality education

1. Introduction

Software is an abstract object that is quite different from physical and digital artifacts. Before software is compiled and successfully deployed, nobody can view, touch, or experience it. Therefore, during software development processes, engineers may encounter unexpected or problems or uncertainty, increasing development risks and costs. To reduce such risks and costs, it is important to apply scientific approaches to design and develop software effectively and efficiently. The major aim of software engineering is to encourage software engineers to apply scientific methodologies to efficiently and effectively develop high-quality software (Cico et al., 2021). Therefore, software engineering education is necessary to teach students the relevant knowledge and skills required for the whole software life cycle. Software engineering education has evolved over the past 30 years, but addressing proper learning with theory and practice is still an open issue (Lin, 2021). The reason is that the implementation of software engineering education in traditional university classrooms is restricted by semester settings, making it difficult to balance theoretical and practical learning activities in traditional university classes (Baker et al., 2005). This means there is scant opportunity to enable students to thoroughly learn software engineering (Garousi et al., 2020).

To balance theoretical and practical learning, prior studies have indicated that flipped learning is a suitable classroom setting for teachers and students (Lee et al., 2021). A flipped classroom is a student-centered pedagogical approach that flips traditional in-class instruction and out-of-class homework. In traditional lecture-based classrooms, students usually carry out lower-level cognitive learning in class, while they are required to perform higher-level cognitive work outside class. In flipped classroom settings, students are usually asked to participate in online learning to acquire knowledge before the class and then to further engage in practical and interactive activities to learn higher-order thinking skills in class. The literature has indicated that in flipped learning, students' learning performance outside class is positively related to their learning performance in class (Birgili et al., 2021; van Alten et al., 2020). Moreover, enhancing and capturing students' learning performance before the class is important to facilitate teachers and students in proceeding with in-class instructions. However, the traditional flipped learning approach cannot support teachers and students conducting learning activities outside the class since students cannot obtain effective learning tools and teachers cannot effectively capture students' learning status. Thus, teachers and students may conduct in-class learning activities on faulty foundations, which may further negatively affect students' learning performance.

In this study, an e-book system named BookRoll was applied to support software engineering education in a flipped classroom setting. The proposed approach supports and facilitates out-of-class and in-class learning by providing reading and learning analytic functions for students and teachers. To explore the performance of the proposed approach, an experiment was designed to investigate students' learning motivation, learning attitude, learning achievement, and problem-solving ability in software engineering education. In addition, students' reading behaviors in the proposed approach were analyzed and discussed.

2. Literature review

2.1. Flipped classroom

Over the past decade, the flipped classroom has been applied at different education levels and in different subjects (Esperanza et al., 2021; Gilboy et al., 2015; Zou, 2020). The flipped classroom was first proposed in 2007 (Roehl et al., 2013; Zengin, 2017). Moreover, numerous studies have presented and advocated the positive effects of flipped learning approaches on students' learning performance (Abdullah et al., 2019; Martínez-Jiménez & Ruiz-Jiménez, 2020; Hwang & Chang, 2020). Furthermore, the literature has reported that students expressed a preference for flipped classrooms over traditional classrooms (Lew, 2016; McNally et al., 2017). Several studies have also indicated that students' engagement is important for improving teaching and learning effectiveness in flipped classrooms (Barkley, 2010; Coates, 2006). On the other hand, investigations have claimed that inappropriate flipped learning settings have a negative effect on students' engagement during the learning process (Patanwala et al., 2017; DeRuisseau, 2016). Related works have concluded that flipped classrooms benefited students' learning performance because the students had enough time to engage in higher-level cognitive learning in class (Lo et al., 2017; Chung et al., 2021). This finding is in accord with the results of Bryson and Hand (2007), who found that students were more likely to engage in high-level cognitive activities with teachers' support.

Previous studies have also pointed out that technology-enhanced flipped classrooms can improve students' learning achievement, facilitate their course participation and satisfaction, and enhance their confidence, creativity and problem-solving ability (Akçayır et al., 2018; Lin, 2016; Yang et al., 2021). Huang et al. (2022) asked students to watch videos and teaching materials before class to understand specific content to be discussed in class. The students in the control group learned with the flipped classroom learning strategy, while the students in the experimental group learned with the flipped learning strategy assisted by business simulation games. The results indicated that the technology-assisted flipped learning approach had a significant positive impact on students' engagement, higher-order thinking skills, and learning performance. Ye et al. (2019) proposed a flipped learning system and used an interactive problem-posing guiding approach to facilitate students' learning before class. The results showed that students who used the approach of the preclass preview had improved learning performance and self-efficacy. Huang et al. (2023) integrated an AI-enabled personalized video recommendation system into a systems programming course in a flipped classroom setting. In the proposed approach, learning videos were recommended according to each student's learning process so that students could learn before and after class. The results showed that the proposed approach improved students' learning engagement and performance with a moderate motivation level.

In addition to the benefits mentioned above, some research issues regarding flipped classrooms remain open. A major issue is the learning performance of students before class, as it affects how teachers and students conduct learning activities in the classroom. In flipped classroom learning environments, students may spend more time previewing before class than the time spent in class. Therefore, the results of previewing before class are very important for learning performance. Most previous studies have focused on the design of classroom learning activities and how to maintain students' participation in preclass learning and improve their self-learning ability (Bond, 2020; Lai et al., 2021; Rasheed et al., 2020). Another challenge is that teachers cannot effectively capture students' learning status before they attend the class. In this circumstance, students may not be able to follow the coursework presented to them in class, or teachers may not proceed with the course as planned. Students with faulty foundations could thus be at risk in taking on learning activities in class. Therefore, it is important to apply an appropriate learning system to support students' out-of-class learning and to assist teachers in capturing students' learning status in flipped classrooms (Hwang & Lai, 2017; Yang et al., 2021). There is a lack of research that allows teachers to effectively understand students' learning behaviors outside the classroom.

2.2. E-book

In the past two decades, with the development and increasing popularity of computer and mobile technology, a trend has emerged of developing e-book resources and technologies to aid students in more efficiently reading, studying, and interacting with learning content. An e-book presents a document in digital form with digital resources and services on certain content platforms, learning systems, or reading software using a computer or mobile device. E-books present the advantages of reading with information technology, such as digitalized bookmarks, annotations, notes, and queries. Moreover, e-books provide digitalization, interaction, and individualization functions to help students read learning materials (Chen & Su, 2019). Several investigations have indicated that these reading technologies can be helpful for students' reading and learning performance (Lin et al., 2013; Sung et al., 2022; Zhao et al., 2021). For instance, Connor et al. (2019) developed e-books to improve primary school students' reading and help them develop a better understanding of words. The results indicated that e-books could enhance students' learning performance and support their development of metacognition. Furthermore, Ni'mah and Umamah (2020) applied e-books to improve students' English skills. The results showed that e-books helped the students improve their English skills and develop reading habits. In addition, the study found that the students had positive perceptions while performing digital reading.

In addition to enhancing students' learning performance, related studies have indicated that a significant amount of logged reading data can be tracked by reading e-books, while those data are much more difficult to track when reading paper-based books (Merkle et al., 2022; Lim et al., 2021). The literature has also shown that learning behaviors and log data are positively related to students' efforts, performances, and outcomes (Huang et al., 2020; Al-Ahdal, 2020). Several studies have reported that the analysis of students' reading behaviors can assist teachers in designing learning materials or learning activities (Sutcliffe & Hart, 2016; Yin et al., 2019). Mouri et al. (2018) proposed an e-book system to support the visualization and analysis of students' reading logs to improve language learning. Boticki et al. (2019) showed that e-books can support teachers in monitoring students' learning status during course delivery and identifying at-risk students early.

Several studies have reported a positive correlation with students' learning performance in different courses by adopting flipped classrooms with e-books (Mukhlisa et al., 2021; Siswanto, 2021; Palinussa et al., 2021). These results have provided evidence that students who learn with e-books can achieve high learning performance in flipped classrooms. The literature has also emphasized that students in flipped classroom settings who used e-books exhibited significant engagement in preclass preparation (Fahmi et al., 2020; Dembedza & Chipurura, 2020). These findings supported flipped classrooms with e-books as a successful approach to improve students' learning performance out of class. Based on the literature review, to promote software engineering education, this study conducted software engineering courses in flipped learning settings. Moreover, an e-book system was adopted to facilitate students' learning in the flipped classroom.

2.3. The importance of learning motivation, learning attitude, and problem-solving ability to learning

Learning motivation refers to the psychological process of arousing students' learning activities, maintaining learning activities, and enabling students to move toward learning goals (Ng, 2018; Ryan & Deci, 2019). Motivation affects students' participation in classroom learning as well as their degree of hard work and perseverance in completing tasks. Students with higher learning motivation will show higher participation in courses and greater persistence in completing tasks. Learning motivation can drive students to study hard automatically and spontaneously and then improve their learning performance. It is a very important factor in the learning process (Wu & Wu, 2020). Therefore, improving learning motivation is very important for learning.

Learning attitude is composed of three components: cognitive, affective, and behavioral intentions, which are embodied in students' attitudes toward courses, teaching materials, teachers, and the school environment (Svenningsson et al., 2022). The cognitive component refers to students' knowledge and understanding of learning activities or courses, which reflects their inner evaluation of learning and is the basis of their learning attitude. The affective component is the emotions or emotional experiences that students produce through cognition. It is the core component that affects learning attitude. The behavioral intention component refers to students' tendency to respond to learning, which is affected by cognitive and affective components, and then engage in certain behaviors (Svenningsson et al., 2022).

Malik et al. (2022) indicated that in programming courses, in addition to focusing on the knowledge teaching of programming logic, students should develop their problem-solving ability. Because the development of problem-solving ability helps students understand the input, procedure, output and other requirements required by the problem task, it has a positive impact on learning behavior and learning attitude. Matturro et al. (2019)

mentioned that team members participating in software development projects become proficient not only in programming skills, such as methods, tools and technologies, but also in problem-solving ability. Shanta and Wells (2022) found that having good problem-solving ability can promote students' understanding of knowledge. Therefore, problem-solving ability is very important in improving students' learning performance.

3. Methodology

To explore the effects of the proposed approach on students' learning performance in software engineering education, this study employed a nonequivalent-groups quasi-experimental design at a Taiwanese university. The scope of software engineering education is related to the software life cycle, which covers system requirement analysis, system design and implementation, system testing and validation, and system maintenance and evolution.

3.1. Participants

The participants were third-year and fourth-year students (aged 20-22 years) from two software engineering classes in the department of computer science at the university. All participants were assigned to two groups according to their class. In all, 64 students were recruited. Twenty-seven students and 37 students were allocated to the control group and experimental group, respectively. Students in the control group participated in software engineering education supported by the flipped learning approach without the e-book system. Students in the experimental group engaged in software engineering education supported by the flipped learning approach with the e-book system. The students in both groups were taught by a teacher with more than 10 years of teaching experience in software engineering education.

3.2. BookRoll E-book system

The BookRoll system was developed by the Ogata Laboratory at Kyoto University (Ogata et al., 2017; Ogata et al., 2015). BookRoll is not only an e-book reading system but also a reading tracker. It has been applied in several academic studies to address different educational issues (Chen et al., 2019; Mouri et al., 2018; Yang et al., 2021). The system is a web application that allows teachers to manage digital learning resources (including e-books and reading status) and enables students to use a web browser to read and mark the e-books anytime and anywhere. Reading functions such as bookmarking, highlighting, e-notes, and searches are provided to support students' reading activities. During the reading process, students' reading behaviors while using the system, including notes, page movements, highlights, bookmarks, and reading progress, are captured and stored in the system database. The e-book system also provides a dashboard to enable teachers to easily and systematically capture aggregated information about students' reading engagement and activity. Moreover, the system integrates several analyzers and aggregators into the dashboard to display students' reading behavior information for teachers, including the number of notes, note contents, the number of red and yellow markers on each page, the degree of reading completion, the contents of highlighted markers, page transition status, and event rate and total numbers over a range of time.

3.3. Instruments

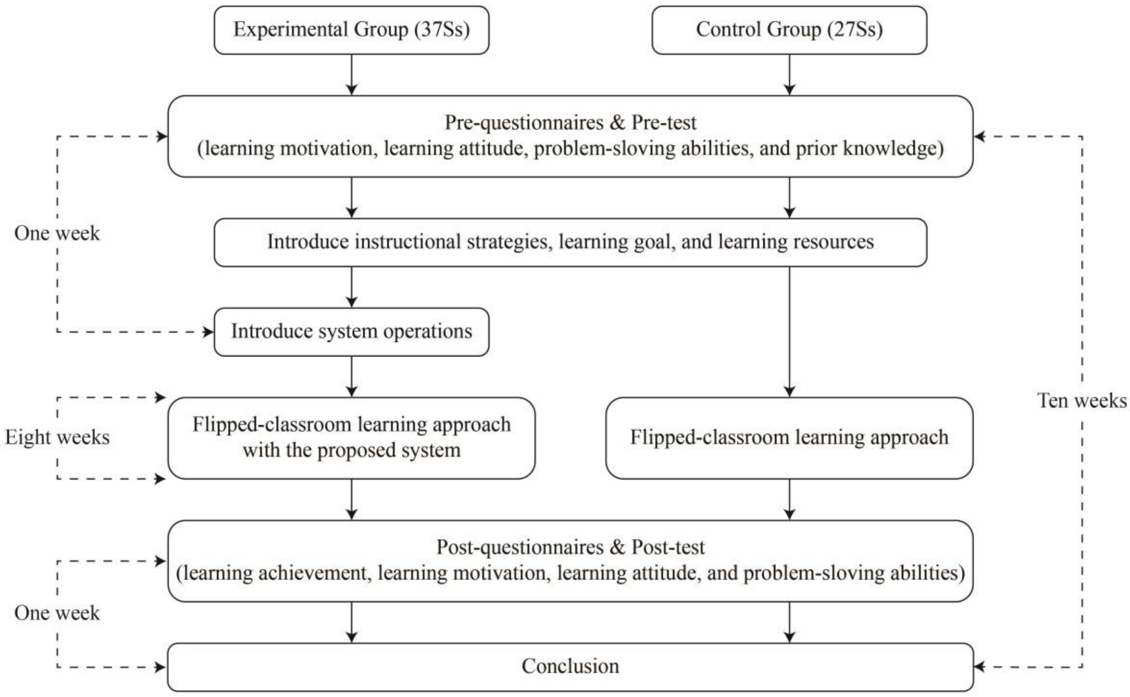
The research instruments used in this study were a learning motivation questionnaire, learning attitude questionnaire, problem-solving ability questionnaire, prior knowledge test, and learning achievement test. In addition, students' reading behaviors collected by the e-book system were analyzed. The prior knowledge test was used to measure students' prior knowledge of software engineering before taking the course. The learning achievement test was used to evaluate students' learning achievement after completing the course. The two tests were conducted as paper-and-pencil tests, and the highest possible score on the two tests was 100. The two tests have been used to evaluate students' knowledge level of software engineering in several software engineering classes (Lin, 2019; Lin, 2021). The reliability, difficulty, and discrimination of the tests have been verified.

With regard to measuring students' learning motivation, the scale of intrinsic value in the Motivated Strategies for Learning Questionnaire (MSLQ) was used as the learning motivation questionnaire with nine items in this study (Erturan Ilker et al., 2014; Lin & Cheng, 2022; Pintrich & De Groot, 1990). Each item was scored on a 7-point Likert scale from 1 (strongly disagree) to 7 (strongly agree). For all students participating in this experiment, the Cronbach's alpha values of the learning motivation questionnaire in the pretest and posttest were 0.919 and 0.948, respectively. The learning attitude questionnaire was proposed by Hwang and Chang (2011) and has been used to survey students' learning attitudes in several studies (Huang & Hwang, 2019; Lin et al., 2018; Liu et al., 2021). It has seven items and uses a 4-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). The reliability values of the pretest and posttest learning attitude questionnaires were 0.849 and 0.922, respectively. To survey students' problem-solving ability, 25 items were referenced and adopted in this study (Lin, 2019; Lin, 2021). Each item was scored on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree). The Cronbach's alpha values of the problem-solving skills questionnaire in the pretest and posttest were 0.856 and 0.845, respectively.

3.4. Experimental procedure

The experiment of the two groups had a length of ten weeks (27 hours), including eight weeks (24 hours) of participating in the software engineering courses and two weeks of taking the pretests and posttests (3 hours). As shown in Figure 1, during the first week, the students in both groups completed three prequestionnaires to survey individual learning motivation learning attitude and problem-solving ability before participating in the formal instruction. Then, all students were asked to complete a prior knowledge test to evaluate their software engineering knowledge. The teacher then spent 30 minutes introducing the flipped learning approach to the students. The students in the experimental group received an additional 20-minute introduction to learn the operation of the e-book system.

Figure 1. The experimental process



During the following eight weeks, the teacher assigned the same e-books and videos to the students in both groups every week. Moreover, the teacher asked each student who had to read and watch the relevant e-books and videos to learn the weekly knowledge prior to attending the class. For this reason, 10 e-books and 61 videos (each approximately 5 to 8 minutes) were produced for this study to support the software engineering courses. The students in the control group used a PDF reader and YouTube player to read and watch the e-books and videos before the weekly class. In contrast, the students in the experimental group used the e-book system and YouTube player to read and watch the e-books and videos before the weekly class. The students in the experimental group were asked to use the bookmark, highlight, and e-note functions of the e-book system to read the weekly e-books. By using the system, the students' reading behaviors, including notes, page movements, highlights, bookmarks, and reading progress, were captured and stored in the database. The teacher could use the dashboard function of the e-book system to capture aggregated information about the students' reading status, such as highlights and notes on each page and reading completion. The teachers could then adjust in-class learning activities according to the students' reading status. In the classroom, the teacher arranged the students in the two groups to conduct discussions, case studies, and practices related to the scope of the software life cycle. During the last week of the experiment, the students in both groups received three postquestionnaires and a posttest to explore individual learning motivation, learning attitude, problem-solving ability, and learning achievement after completing all learning activities.

4. Results

4.1. Learning achievement analysis

This analysis was conducted to investigate the difference between the two groups in terms of learning achievement. To perform the analysis, the equivalent of the students' software engineering prior knowledge was first examined by an independent sample *t*-test. The mean value and standard deviation of the students in the control group were 34.00 and 17.32, respectively. Those values of the students in the experimental group were 36.21 and 14.59, respectively. To confirm the normal distribution of the data, the Kolmogorov-Smirnov test (KS test) was conducted because the number of samples in the analysis was larger than 50. The KS test result (F = .121, p > .05) indicated that the data were normal. Then, the homogeneity of variance was assessed by Levene's test, and the results showed that the within-group variances were equal (F = .868, p = .355 > .05). The results of the independent sample *t*-test showed no significant difference between the two groups with regard to prior knowledge of software engineering ($t(1, 62)$ = .644, p = .589 > .05).

To check for the difference in learning achievement depending on the different flipped learning approaches among the two groups, a one-way ANCOVA was employed after the impact of the students' prior knowledge was neutralized. The assumption of homogeneity of the regression slope (F = 1.038, p > .05) was not violated, revealing that the ANCOVA was suitable. Table 1 tabulates the ANCOVA results for learning achievement for the two groups. The average learning achievement score was significantly higher for the experimental group than for the control group ($F(1, 61)$ = 10.431, p = .002 < .05). The results show that in terms of learning achievement, the flipped learning approach with the e-book system was better for students than the flipped learning approach without the e-book system.

Table 1. ANCOVA results of learning achievement for the two groups

Group	*n*	Mean	Standard deviation	Adjusted mean	Adjusted Standard deviation	*F*	*p*-value
Experimental group	37	89.18	14.01	88.99	2.33	10.431	.002*
Control group	27	76.80	15.19	77.09	2.84		

Note. $^*p$ < .05.

4.2. Learning motivation analysis

In this analysis, one-way ANCOVA was used to determine whether students in the two flipped learning approaches had significant differences in the learning motivation scores on the postquestionnaire. ANCOVA was employed with the scores of the learning motivation prequestionnaire, the scores of the learning motivation postquestionnaire, and the learning approach as the covariate, dependent variable, and independent variable, respectively. The test of homogeneity showed that the assumption of regression homogeneity was not violated, with F = 1.127 and p = .293 > .05, indicating that ANCOVA can be used for learning motivation analysis.

Table 2 tabulates the ANCOVA results, which indicate that the post learning motivation scores of the two groups were significantly different, with $F(1, 61)$ = 4.140 and p = .046 < .05. That is, the students in the experimental group had significantly higher learning motivation than those in the control group, indicating that the flipped learning approach with the e-book system was beneficial to the students' learning motivation in the software engineering course.

Table 2. ANCOVA results of learning motivation for the two groups

Group	*n*	Mean	Standard deviation	Adjusted mean	Adjusted Standard deviation	*F*	*p*-value
Experimental group	37	6.06	0.82	6.07	0.12	4.140	.046*
Control group	27	5.67	0.69	5.66	0.15		

Note. $^*p$ < .05.

4.3. Learning attitude analysis

This analysis was conducted to evaluate the effects of the proposed learning approach on students' learning attitudes toward software engineering education. ANCOVA was employed with the scores of the learning attitude prequestionnaire, the scores of the learning attitude postquestionnaire, and the learning approach as the covariate, dependent variable, and independent variable, respectively. The test of homogeneity showed that the assumption of regression homogeneity was not violated, with $F = .353$ and $p = .555 > .05$, revealing that ANCOVA can be used to analyze learning attitude scores.

Table 3 presents the ANCOVA results. The results show a significant difference between the two groups in the learning attitude postquestionnaire ($F(1, 61) = 7.524$, $p = .008 < .05$). This means that the use of the flipped learning approach with the e-book system positively affected the students' learning attitude. More specifically, students who engaged in the flipped learning approach with the e-book system significantly benefited in terms of learning attitude compared to those who engaged in the flipped learning approach without the e-book system.

Table 3. ANCOVA results of learning attitude for the two groups

Group	*n*	Mean	Standard deviation	Adjusted mean	Adjusted Standard deviation	*F*	*p*-value
Experimental group	37	3.54	.44	3.55	.07	7.524	.008*
Control group	27	3.25	.41	3.24	.08		

Note. $^{*}p < .05$.

4.4. Problem solving ability analysis

One-way ANCOVA was utilized to measure the students' problem-solving ability using the scores of the problem-solving ability prequestionnaire as covariate, the scores of the problem-solving ability postquestionnaire as a dependent variable, and the learning approach as an independent variable. The test of homogeneity showed that the assumption of regression homogeneity was not violated ($F = .634$, $p > .05$), indicating that ANCOVA can be used to conduct problem-solving ability analysis.

Examination of the effectiveness of the flipped learning approach with the e-book system in terms of problem-solving ability through ANCOVA showed that there was a significant difference between the experimental group and the control group, with $F = 4.755$ ($p = .033 < .05$), as shown in Table 4. The results indicate that the statistically significant effect ($\alpha = .05$) on the problem-solving ability postquestionnaire was attributable to the learning approach, as the students in the experimental group, who learned in the flipped learning approach with the e-book system, performed better than their counterparts in the control group, who learned in the flipped learning approach only.

4.5. Reading behavior analysis

This study further analyzed the reading behaviors of students in the experimental group using reading logs from the e-book system. The reading logs covered reading time and reading completion. The reading time indicates that a student spends a certain number of minutes reading the e-books during the learning process. The reading completion is a student's average reading completion of all e-books during the entire learning process.

Table 4. ANCOVA results of problem-solving ability for the two groups

Group	*n*	Mean	Standard deviation	Adjusted mean	Adjusted Standard deviation	*F*	*p*-value
Experimental group	37	3.71	.43	3.72	.06	4.755	.033*
Control group	27	3.50	.21	3.49	.08		

Note. $^{*}p < .05$.

The simple linear regression analysis method was utilized to predict students' learning achievement based on their reading time and reading completion. Students' learning achievement is the dependent variable. Students' reading time and reading completion are independent variables. The regression coefficient values and analytic results are presented in Table 5. The results indicate that there was a significant positive correlation between reading time and learning achievement in this study. This means that as students' reading time increased, their learning achievement also increased. It is noteworthy that reading completion did not significantly predict student learning achievement.

Table 5. Analyzing correlations among reading behaviors and learning achievement by linear regression

Predictor	R^2	Adjusted R^2	B	t	p
Reading time	.578	.313	.104	4.002	$.000^*$
Reading completion	.281	.050	.171	1.657	.107

Note. $^*p < .05$.

5. Discussion and conclusion

The proposed flipped learning approach provides students with better learning performance in acquiring software engineering knowledge and better supports teachers in monitoring students’ learning status in a flipped learning process. Furthermore, in terms of learning out of class, the students benefited more and were more motivated to conduct the learning activities. The contribution of the proposed approach is twofold. First, it helps students improve their software engineering learning performances through using the e-book system to efficiently construct relevant knowledge out of class and further engage in mastering the knowledge during the in-class case studies, discussions, and practices in the flipped learning setting. Second, this approach helps teachers improve flipped learning instruction by using the dashboard of the e-book system to effectively and efficiently monitor students’ learning status before the class. In this study, to monitor the students’ weekly learning status out of class, the teacher first observed the reading rate of the e-books of the whole class from the system dashboard before the students attended the class. Moreover, the teacher further observed the students’ notes and highlights on each page of the e-books to capture what the students may not have understood. Furthermore, the average reading time for each page in the e-books could be used by the teacher to judge whether the students had encountered difficulties in learning the contents. By using various learning analytic functions provided by the e-book system, teachers can effectively and efficiently capture students’ learning status before class and make adjustments to learning activities in class in real time.

The experimental results support the positive impacts of the proposed approach on students’ learning motivation, learning attitude, learning achievement, and problem-solving ability in software engineering education. The results support the contention of Bergmann et al. that the application of appropriate technologies is a significant element to positively motivate students’ learning and affect their attitude in flipped classrooms (Bergmann & Sams, 2012; Lin, 2019; Oweis, 2018). This study used a web application (the e-book system) that provides suitable reading functions to enable students to use a web browser to effectively and efficiently study course materials anytime and anywhere. The increased motivation and attitude can also be attributed to flipped learning programs that can be reinvented to satisfy the individual needs of students in a program (Lin, 2021). Horn (2011) argued that a student’s interest is motivated when she or he can identify with the materials that are used in the learning process. Regarding students’ learning achievement, the results of the proposed approach were significantly better than those for students learning without the e-book system in a flipped classroom. This discovery conforms to the study of Haghighi et al. (2019) where students who learned with appropriate tools before class could enhance their engagement in class and further improve their learning achievement in a flipped classroom. The argument also supports the results for students’ problem-solving ability found in this study. The analysis showed that students learning with the proposed approach had higher problem-solving ability than those learning with only the flipped learning setting. This discovery supports the studies of Chang and Hwang (2018) and Kurnianto et al. (2019) in that when students build fundamental knowledge out of class in a flipped learning environment, they are able to engage in in-class learning activities and better develop higher-order thinking abilities, such as problem-solving ability. Students with good prior knowledge are able to better articulate concepts, illustrate and construct interrelationships among concepts, and generate higher levels of thinking (Alamri, 2019; Cai & Gu, 2022; Mamun et al., 2020).

Despite the valuable contributions of the research results, the present study also had some limitations that should be acknowledged. First, as a result of university semester considerations, this study did not adopt random selection to distribute the participants in the control and experimental groups. Second, the sample size was not large, so the results cannot be generalized to possible learning performances in different contexts and applications. In addition, this study was conducted in an Asian country. The research settings and results might not be directly applicable to software engineering classes in other countries with different cultures, educational policies, or learning environments. According to the literature review, most of the research related to flipped classrooms still focuses on the learning performance of students before class. However, future research should focus on what kind of instructional design framework to use to plan the entire flipped classroom approach rather than just emphasizing preclass learning (Lo & Hew, 2017). In other words, researchers can further design in-class learning activities to teach students higher-level thinking ability based on the current research foundation of flipped classrooms. For instance, in class, teachers can use problem-based learning approaches to guide students to develop their problem-solving ability in combination with the development of their mental processes (Lin & Lin, 2016).

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