An Empirical Evaluation of Online Cooperative Programming Platforms Based on the PACT Framework and Technology Readiness

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Abstract

Programming instruction helps students develop critical-thinking and problem-solving skills, and is also important for the development of professional talent in the information technology sector. Cooperative learning has been shown to promote innovative educational applications while enhancing learning motivation and performance. Referring to the People, Activities, Context, Technologies (PACT) framework and the theory of technology readiness, this study explores factors that affect continued use intention and learning performance for students using an online cooperative programming (OCP) platform. A total of 120 students were invited to participate in the programming course. Students were asked to complete programming projects on the OCP platform and fill out a questionnaire. A causal model was proposed and examined using a partial least squares regression. The results show that optimism/ innovativeness in technology readiness and trust among team members both have a positive impact on user satisfaction using the platform. In addition, both user satisfaction and trust encourage continued use intention and improve learning performance. The findings can help educators and researchers promote the development of programming teaching and learning.

Keywords: Online cooperative programming, PACT framework, Technology readiness, Continued use intention, Visual studio team services

1 Introduction

Programming is a basic literacy skill in the digital age [1]. Many researchers have indicated that programming can help people improve their computational thinking, creativity and problem-solving skills, thus better preparing them to face future challenges [2-3]. Learners can apply the skills from programming courses in other disciplines [4]. However, many students find programming difficult to learn. They are unable to effectively and independently perform the description-execution-reflection-debugging-description actions which form the basis of the programming process [5], and have particular trouble with debugging processes. Learners are often confused by syntax and commands, which makes it difficult to acquire advanced programming skills [6].

Some researchers have suggested incorporating cooperative learning activities into teaching design [7-9]. Slavin [10] pointed out that cooperative learning provides learners with various benefits, including information inquiry, exchange of ideas, resource sharing, and progress monitoring among students. Hwang et al. [11] also suggested that cooperative learning can help enhance learning motivation, participatory intention, and programming performance. When working collectively on a project, students can learn together, support each other, and share experience to achieve certain learning goals [12]. Overcoming initial programming obstacles through the help of learning peers can help novice programmers develop increased motivation and interest in programming, thus producing better learning outcomes.

Most previous studies of the effects of technology-aided learning on learning satisfaction and learning performance focused primarily on the usefulness and ease-of-use of information systems, while neglecting the importance of interactions. Particularly in online cooperative programming (OCP) environments, users must discuss and negotiate amongst themselves through online communications systems. This study emphasizes the impact of people-technology and

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people-people interactions on learning satisfaction based on the People, Activities, Context, Technologies (PACT) framework. Through active interaction and knowledge exchange, the OCP platform is expected to help students improve learning performance in programming courses.

2 Literature Review

2.1 People, Activities, Contexts, Technologies Framework

The PACT framework derives four major components from human-computer interaction: people, activities, contexts, and technologies [13]. In the design process of human-computer interaction and interactive systems, the following questions must be carefully considered: what do users need, how should interactive systems respond, and how should the information obtained be processed in the interaction process? The structure of PACT explicitly covers various social and technical issues. User-friendly user interfaces are an important key to continued system use [14]. PACT is an evaluation framework which can be used to ensure system user-friendliness and to provide users with a deeper understanding of existing systems [15].

As shown in Figure 1, the PACT framework emphasizes people, technological features, and interactions between them. The proposed framework is based on the technology characteristics and the relationship between people and technologies in the PACT framework, as well as trust between people.

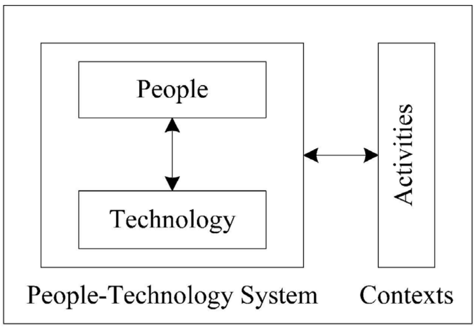

Figure 1. The PACT framework [13]

2.2 Technology Characteristics

Vessey and Galletta [16] suggest that, if the characteristics of a particular type of information technology can support a user's task, it can improve user performance. Goodhue and Thompson [17] define technology characteristics as the software, hardware, and services associated with the realization of work goals. According to their concept, assuming people are rational decision makers, they are likely to adopt certain systems to improve work performance, even if they dislike them [18]. Goodhue [19] points out that technology characteristics can be observed according to their degree of integration, the popularization of workstations, number of information technologies, and ratio and divergence of assistance personnel.

In general, the user will expect to use an information system as long as it contributes to his/her work performance. Reasonable and experienced users will assess the benefits of new technologies before deciding which (if any) to use. The decision to adopt a new technology is mostly related to the technology's ability to meet and support the characteristics of the user's work. The technology examined in this study is an OCP platform, which can be assessed in terms of functionality completeness, debugging inspection convenience, and coordination and communication capabilities.

2.3 People and Technology: Technology Readiness

From the perspective of psychology, Parasuraman and Colby [20-21] defined technology readiness as the propensity to accept and use new technologies to achieve goals in everyday life or work, where the positive driving factors include optimism and innovativeness, while negative suppressing factors include discomfort and insecurity. Optimism represents a positive view of technology, which is the belief that technologies can help increase efficiency, control, and flexibility. Innovativeness means the intention to be technology innovators or the tendency to apply creativity. Discomfort occurs when people find it difficult to adapt to new technologies due to perceived lack of control. Insecurity refers to a mistrust that a technology can be used appropriately.

Users' optimistic and innovative characteristics can affect their satisfaction [22]. Bhattacherjee [23] pointed out that user satisfaction with an information system will affect their intention of continuous use, and their long-term use intention can be enhanced by improving satisfaction. The concept of technology readiness contains the intention of using that new technology [24]. Therefore, higher technology readiness means that users have greater interest and ability to use cooperative programming software, leading to higher levels of satisfaction and usage intention.

2.4 Interaction between People: Trust

Olfman and Mandviwalla [25] regard cooperative technology as a socio-technical system. The main technological characteristics include the functionality of communication and the facilitation of interaction and collaboration. This further demonstrates the important role of interpersonal communication in cooperative technology. Trust among team members can improve teamwork performance. Many studies have assessed trust [26-27]. Lewicki et al. [28]

proposed that trust is a comprehensive confidence or faith in the trust object. Sirdeshmukh et al. [29] discussed the mutual trust relations between partners, concluding that the two sides of trust simultaneously play both trustor and trustee. This suggests that trust is a mutual, interactive, and dynamic relationship.

In this study, trust is defined as an interactive, bilateral, and dynamic relationship between a trustor and trustee. It is a faith or expectation in others, as well as the intention to depend upon others with a willingness to take risks, indicative of a mutually dependent relationship.

2.5 Satisfaction

The concept of user satisfaction was initially proposed by Cyert and March [30] in their book "A Behavioral Theory of the Firm," which suggests that users' information satisfaction is increased if information systems can meet their work requirements, and satisfaction will decline if user requirements are not met. Porter [31] believes that satisfaction is mostly determined by the difference between the work expectation and actual achievements. That is, satisfaction comprises a personal cognition of the discrepancy between the "deserved" and the "actually obtained." Locke [32] thinks that job satisfaction is the difference perceived by a person between her/his expectation and the result, with a smaller discrepancy indicating higher satisfaction. In other words, job satisfaction includes the perceived distance between one's conscious/subconscious expectations and needs (and ambition to achieve personal values), and actual accomplishments.

Many studies have noted a positive correlation between learning satisfaction and learning performance in programming courses [33-34]. Students are generally more satisfied with pair programming than solo work, and pair programming has been found to effectively improving assignment performance.

2.6 Continued Use Intention

Whether a system's service functions can meet a users' needs is a critical factor affecting the users' intentions to continue using an information system. Oliver's expectation-confirmation theory discusses customer satisfaction with products or services, suggesting that customer intention to repurchase or continue use is affected by their degree of satisfaction [35]. Bhattacherjee [23] found that continuance intention is similar to repurchasing intention in terms of the impact of the user's first-time experience with a given information system. Based on Oliver's theory, Bhattacherjee proposed the post-acceptance model of information system continuance to discuss continuance intention towards a product; the continuing usage intention of a system is dependent on user satisfaction. This approach uses continuance intention to predict and elucidate user continuance behavior for an information system. The present study also uses continuance intention instead of behavioral intention to predict practical behavior.

3 Research Methods

3.1 Online Cooperative Programming Platform: Visual Studio Team Services

Visual Studio Team Services (VSTS), an OCP platform developed by Microsoft, was used in the programming course. VSTS is a powerful team development tool that allows programmers to collaboratively code and debug for a team task. VSTS provides a team development platform for case management, version control, project management, testing, and building. It supports multi-platform/technology development teams, does not require server or software installation, and allows immediate access upon registering an online account. VSTS facilitates cooperative work in a group chat room, asking for user opinions, portfolio management, establishing job item diagrams, and web testing case management. It also allows students to conduct cooperative design and analysis, as well as to record and exchange thoughts in practice.

3.2 Research Model and Hypotheses

This study proposes a research model that uses the PACT framework and theory of technology readiness to investigate students' behaviors and performance when they use an OCP platform to learn programming. The factors influencing student attitudes and behaviors were divided into three dimensions: technology characteristics, opinions on technology, and interactions among people. People's opinion on technology was discussed from various aspects of technology readiness, while the people-people relationship was measured using the concept of trust. This study focuses mainly on the influences of technology characteristics, technology readiness, and trust on user satisfaction. The correlations of user satisfaction with continued use intention and learning performance were also explored. Of the four original dimensions for technology readiness (optimism, innovativeness, discomfort, and insecurity), the insecurity dimension was not included in the research model because there are fewer security concerns for programming learning, and VSTS provides a stable and secure development environment. The research model is shown in Figure 2.

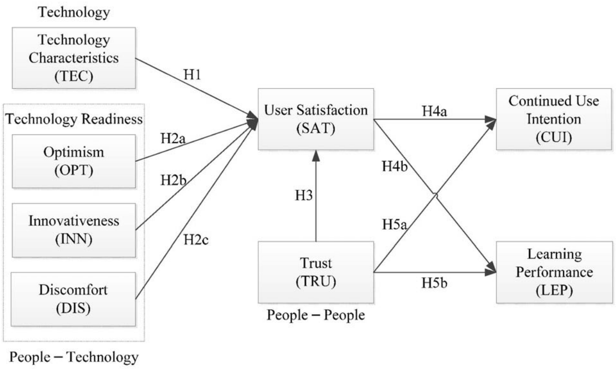

Figure 2. Research model and hypotheses

According to the research model, the following hypotheses are proposed for the OCP environment in this study:

H1: Technology characteristics positively influence user satisfaction.

H2a: Optimism positively influences user satisfaction.

H2b: Innovativeness positively influences user satisfaction.

H2c: Discomfort negatively influences user satisfaction.

H3: Trust positively influences user satisfaction.

H4a: User satisfaction positively influences continued use intention.

H4b: User satisfaction positively influences user learning performance.

H5a: Trust positively influences continued use intention.

H5b: Trust positively influences user learning performance.

3.3 Research Tools

Programming students typically find independent debugging to be one of the greatest challenges. Through the OCP platform, students can help each other and cooperate as a team when encountering problems at the debugging stage, thus minimizing frustration and enhancing their interest in programming. Moreover, this kind of cooperation can help students improve their programming skills and teamwork. The cooperative learning procedure for programming is shown in Figure 3.

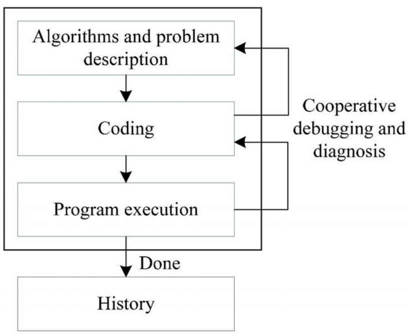

Figure 3. Cooperative programming procedure

The questionnaire design was adapted from relevant instruments taken from previous studies showing satisfactory reliability and validity. The questionnaire was examined by two experts in information systems education to ensure its content validity. The question items corresponded to seven dimensions in a five-point Likert scale from 5 (“very satisfied”) to 1 (“very dissatisfied”).

3.4 Data Collection

Study participants included 120 information management majors taking a program design course in the second semester of their university freshman year. They were randomly assigned to pairs. During the first nine weeks, students learned the basic concepts of programming and the functions of the OCP platform. Over the following nine weeks they were asked to complete some team projects using the OCP platform. This process helped students familiarize themselves with the OCP platform and then evaluate its actual benefits.

Learning performance was assessed using the questions in the “Technoficiency quotient certification for object-oriented interface and database programming,” certification scheme offered by the Computer Skills Foundation. This study selected three categories of technical questions (basic program flow control, object program design, and database application development) as test questions with a maximum score of 5.

The questionnaire was distributed to participants after the end of the course. Excluding 9 invalid responses left 111 valid questionnaires (81 male and 30 female). In terms of programming experience, 58% of participants had less than one year, while 22.52% had between 2 and 3 years, and the remainder had between 4 and 5 years.

4 Results

4.1 Reliability Analysis

Reliability refers to the consistency or stability of measurement results. Measurement errors were determined to reflect the truthfulness of the measurement results. In this study, the Cronbach’s α coefficients for all seven dimensions investigated exceeded the standard value of 0.7 proposed by Nunnally [36].

4.2 Measurement Model

Table 1 summarizes analysis results for reliability, convergent validity, and discriminatory validity. The composite reliability of each dimension in the model exceeded 0.80. The average variation extraction (AVE) of each dimension exceeded the recommended value of 0.5 [37]. This parameter was used to evaluate the explanatory power of all questionnaire items regarding the variations in the corresponding dimension. A higher AVE indicates a higher reliability and convergent validity of this dimension. In addition, to evaluate the discriminatory validity, the AVE value and shared variation among individual dimensions were compared [38]. The shared variation between dimensions must be lower than the AVE value of individual dimensions. Overall, the measurement models showed an appropriate reliability, convergent validity, and discriminatory validity.

Table 1. Reliability, convergent validity, and discriminatory validity

	M	SD	CA	TEC	OPT	INN	DIS	TRU	SAT	CUI	LEP
TEC	3.92	.61	.76	.90							
OPT	4.03	.66	.81	.69	.82						
INN	3.73	.68	.73	.59	.59	.89					
DIS	3.36	.70	.74	.39	.25	.31	.81				
TRU	3.83	.66	.87	.76	.70	.67	.30	.89			
SAT	3.88	.61	.89	.80	.74	.77	.34	.85	.87		
CUI	3.77	.70	.92	.72	.68	.68	.33	.79	.84	.92	
LEP	3.80	.62	.84	.73	.75	.75	.39	.82	.86	.85	.87

Note. M is the mean value; SD is standard deviation; CA (Cronbach's α) is reliability; AVE is average variation extraction value. The diagonal line is the square root of AVE value; the off-diagonal line is the correlation coefficient of the shared variation with the related numerical value on the variable diagonal line among each dimension.

4.3 Structural Model

Following a two-stage evaluation model and bootstrapping resampling technique, Figure 4 shows the standardized path analyses and their corresponding significance levels. Several research hypotheses were proposed based on the relevant literature and the relationships among the variables. Bootstrapping, which is a non-parameter estimation method, was adopted to estimate the distribution of parameters via the resampling of the statistical data. The results show that cooperative technology characteristics, optimism/ innovativeness in technology readiness and trust among team members all have a positive impact on user satisfaction with platform usage experience. In addition, both user satisfaction and trust are positively correlated with continued use intention and learning performance. Therefore, in this research model, except for hypothesis 2c, hypotheses 1 to 5 are all supported. The explanatory power of technology characteristics, people–technology relationships, and people–people relationships on user satisfaction is 84.2%. The explanatory power of user satisfaction and trust on the factor of continued use intention is 72.9%. The explanatory power of user satisfaction and trust on learning performance is 77.3%.

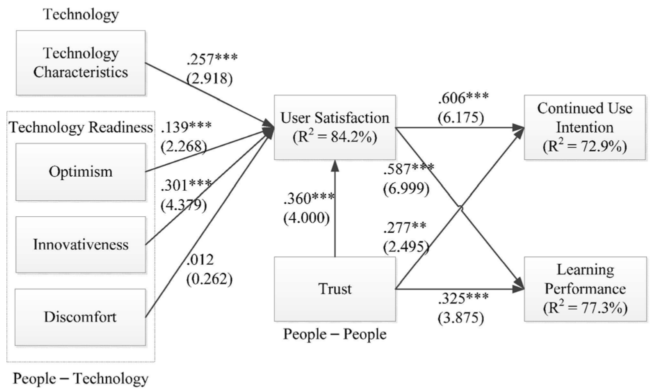

Figure 4. Analysis results

Notes. * represents $p < 0.05$; ** represents $p < 0.01$; *** represents $p < 0.001$. The numerical value not in parenthesis is path coefficient, and the numerical value in parenthesis is the *t*-value.

5 Discussion and Implications

In the past, software acceptance was mostly discussed from the perspective of the technology acceptance model (TAM) and its related theories, such as the unified theory of acceptance and use of technology (UTAUT) [39]. This study proposes an alternative and important point of view, focusing on learner attitudes, intentions, and behaviors towards the use of OCP platforms in terms of technical characteristics, people–technology relationships, and people–people relationships. The correlations among all variables in the framework were analyzed using the path analysis method, and the results showed that the explanatory ability of the overall model was high.

Among all of the factors influencing user satisfaction with OCP platforms, the people–people relationship plays the most important role, followed by user impressions on technology, with technology characteristics being the least important. The results show that, because cooperative programming is indeed a teamwork-based development model, users are inevitably most concerned with trust among team members. Technology readiness, i.e., the user's opinion on a given technology, is of secondary importance. The characteristics of the technology impose the least influence. Among the five hypotheses, only hypothesis 2c was found to be unsupported, with user discomfort having an insignificant impact on user satisfaction. Five respondents were interviewed to investigate the issue. Frequent practice (four hours per week) using the OCP platform was found to strengthen users' ability to manipulate the platform and reduce discomfort. The cooperative functions provided by VSTS can help learners overcome difficulties in learning to program through mutual cooperation among peers. In addition, most students are already familiar with the use of the Internet and information technologies, and thus found VSTS to be somewhat familiar. As a result, user discomfort had no significant influence on user satisfaction with the OCP platform.

This study contributes to academic research and educational practice. In terms of the academic implications, using the PACT framework and technology readiness theory, this research investigated the impact factors for continued usage intention and learning performance for OCP platforms in programming classes. The results showed that technology characteristics, technology readiness, and trust among team members are all positively correlated to user satisfaction. In addition, when using the platform to learn program design, user satisfaction and trust among team members are also positively correlated with continued use intention and learning performance.

In terms of the practical implications, this study provides a good reference for educators to design appropriate teaching/learning approaches to assist students in learning to program. In fact, many information technologies (ITs) have emerged with the aim of facilitating learning. Teachers can use these technologies and their related applications to facilitate cooperative learning and thus enhance learning motivation and performance. Programming instruction must be designed to match student needs and thus promote satisfactory learning outcomes. Programming mostly involves the process of task description, program execution, re-check, debugging, and task description, which is very difficult for most students to complete independently. The OCP platform can help students overcome difficulties in their programming workflows, and allows students to cooperate with and learn from each other, thus significantly improving learning motivation, satisfaction, and performance.

6 Conclusions

Many previous studies have examined the application of cooperative learning in various fields. However, relevant research concerning the application of OCP platforms for programming is still at an initial exploratory stage. Therefore, this study evaluates the use of OCP platforms in programming courses, with the objective of improving student satisfaction, learning performance, and continued use intention in the related classes. Through investigating and analyzing the effectiveness of OCP platforms and user learning performance in university level programming courses, the results from this study can provide practical experience and a theoretical basis for researchers participating in related projects for educational applications of OCP environments.

The results from this study provide an important reference for the development of online teamwork platforms for teaching programming, thus enhancing competitiveness in programming training and improving student prospects in digital learning fields. In addition, while cooperative learning emphasizes active learning on the part of students, the role of the teacher is equally important. Teachers should guide cooperative learning and seek to increase teacher–student interaction. Cooperative learning requires significantly more attention and patience from teachers to assist students in achieving their best learning performance.

This study focused mainly on the viewpoints of technology, people–technology relationships, and people–people relationships, and did not account for factors such as learning style and previous programming ability. These and other impact factors should be considered in future research.

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