**Edelweiss Applied Science and Technology**
*ISSN: 2576-8484*
*Vol. 8, No. 5, 395-405*
*2024*
*Publisher: Learning Gate*
*DOI: 10.55214/25768484.v8i5.1696*


# Enhancing digital competence of prospective vocational teachers using project-based learning with the technological pedagigical content and knowledge approach

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**Abstract:** Prospective teachers must prepare students with 21st-century skills using digital technology, known as digital competence. The importance of digital competence for prospective vocational teachers encourages study to develop an innovative instructional model, namely Project Based Learning (PjBL) with the technological pedagogical content and knowledge (TPACK) approach, which focuses on enhancing the digital competence of prospective teachers in vocational education. This research aims to investigate the effect of the PjBL instructional model with the TPACK approach on enhancing the digital competence of prospective vocational teachers. This study used quasi-experimental research in two universities in Yogyakarta, Indonesia. The sample used was 102 prospective vocational teachers consisting of 45 prospective teachers in the control class and 57 prospective teachers in the experimental class. The digital competency measurement items include 30 statements. Data analysis in this study used an independent t-test. The results of the independent t-test conclude that there was a significant difference. The results concluded that the post-test digital competency score of the experimental group students increased with a score of 79.19, while the control group 58.39. The practical implication of the application of this model is that educators can apply it to improve the competence of prospective vocational teachers with indicators relevant to the material through learning media creation project activities. Recommendations for further research are to compare the effectiveness of PjBL with various other instructional models with the TPACK approach to develop digital competence of prospective teachers and involve wider samples such as between regions or countries.

***Keywords:*** *Digital competence, Project based learning, Prospective teacher, TPACK approach, Vocational education.*

## 1. Introduction

Teachers have an essential role in the digital instructional era [1], [2]. The quality of education depends on teachers [3]. They must have the competencies [4]. Given the importance of the role of teachers, it can be started by preparing the competence of future prospective teachers. Prospective teachers must prepare students with 21st-century skills using digital technology, namely digital competencies. Digital competence is one of the competencies that prospective teachers must have to face adulthood and survive [5]. It requires guidance to apply media sources and creation tools [6]. Integration of Information and Communication Technology (ICT) can enhance 21st-century learning competence for students in the curriculum [7], [8].

The use of technology for learning purposes cannot be ignored. Although content is considered important for teachers, pedagogical strategies have an important role in optimizing student learning


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[9]. The demands of learning in the digital era are learning that integrates technology. In addition, various advantages of the learning process when integrated with technology have also been proven. The existence of technology makes learning activities more student-centered [10]. Various studies have shown that the use of technology in learning properly can enhance student competence in learning [11]–[13]. Digital technology effectively opens up opportunities for individual, flexible, and future-oriented training, specialists taking into account the principle of continuity. ICT is a good facilitator and collaborator in the instructional process that requires students to be more active.

Digital competencies include access, management, development, and evaluation of digital devices and applications [14]. It plays an essential role in learning practices, so educators must design the right learning environment and choose effective learning media. Technology influences the learning environment [15]. Vocational school teachers must adapt to develop skills in ICT to face the challenges of work in the future.

Technological Pedagogical, Content, and Knowledge (TPACK) is a theoretical framework that describes teachers' knowledge needs to effectively integrate technology into learning practices [16]. The rapid development of the TPACK approach has redesigned teacher education programs in recent decades [17], [18]. Polly et al. stated that most teacher education has attempted to develop TPACK for prospective teachers through stand-alone educational technology courses in the last decade, which are digital competence-oriented [19].

Educational Personnel Training Institute (in Indonesia Lembaga Pendidikan Tenaga Kependidikan/ LPTK) has the challenge of preparing future teacher candidates who can integrate technology effectively [20]. The digital literacy skills of prospective vocational teachers of Universitas Sarjanawiyata Tamansiswa are still in the low category. LPTK is required to equip teachers with digital competence [21]. In addition, teacher education programs in Indonesia have not been structured based on a clear professional development framework. One of the priorities is the digitalization of education, which primarily includes the intensification of the instructional process, the implementation of the ideas of adaptive learning and development, the improvement of forms and methods of organizing the learning process, and the creation of an education system focused on modern digital technologies.

Graduates of prospective vocational teachers need to be equipped with digital competence. The PjBL instructional model has become a focus in vocational education studies because of its effectiveness in enhancing students' practical competencies [22], [23]. The importance of digital competence for prospective vocational teachers encourages research to develop an innovative instructional model, namely PjBL with TPACK approach, which focuses on increasing the digital competence of prospective teachers.

The research questions include: i) Does the treatment between the PjBL and TPACK approach show differences in pre-test and post-test scores for digital competence? ii) What is the effective contribution of using the PjBL instructional model with the TPACK approach in enhancing prospective vocational teacher digital competence?

## 2. Literature Review of PjBL Instructional Model with TPACK Approach

Philosophical concepts and didactic methods of teaching and learning strategies are the basis for developing instructional models. The instructional model is certainly straightforward, planned, and flexible, which means that adjusting the needs of the teaching materials contained in the learning plan is a determining factor in choosing an approach [24]. Project Based Learning (PjBL) was introduced by American philosopher John Dewey in 1916 [25]. Dewey argued that students should actively learn based on their experiences. In addition, the theory underlying PjBL also comes from the constructivism view and connectivism theory [26]. Vygotsky's concept of "zone of proximal development" (ZPD) is particularly relevant in PjBL, as projects are often designed to require students to work slightly beyond their current abilities with support from teachers and peers [27].

The steps of the PjBL instuctional model that have been developed in previous studies include 1) starting with a question, 2) determining the project, 3) conducting research and collecting resources, 4)

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 8, No. 5: 395-405, 2024*
*DOI: 10.55214/25768484.v8i5.1696*

creating and refining the product, 5) presenting the final product, and 6) reflecting on the process [28]–[30]. Through these steps, the PjBL instructional model not only focuses on the final result, but also on a continuous, collaborative, and reflective learning process. The PjBL in vocational education can help students develop practical skills, critical thinking, and digital competencies that are relevant to the needs of industry. It is effective in enhancing students' collaboration and critical thinking skills [31], [32]. This instructional model can also improve students' creativity because students are required to plan, implement, and evaluate their learning activities independently [32]–[34]. In addition, PjBL is consistent with the principles of constructivist learning which emphasize the importance of active, experiential, and student-centered learning.

The TPACK approach is an extension of PCK by adding technological aspects as a special type of teacher knowledge [35]. The TPACK approach in the vocational field emphasizes the content knowledge component of vocational knowledge. Wheelahan [36] defines vocational knowledge as applied disciplinary knowledge, correlated with the objectives of the vocational curriculum, namely to encourage student mastery of the field of practice and theoretical knowledge that supports the practice. As an illustration of the learning trajectory, namely how much teachers have been involved in activities related to the knowledge components: technological knowledge (Technological Knowledge/TK), pedagogical knowledge (Pedagogical Knowledge/PK), content knowledge (Content Knowledge/CK), technological pedagogical knowledge (Technological Pedagogical Knowledge/TPK), pedagogical content knowledge (Pedagogical Content Knowledge/PCK), and technological content knowledge (Technological Content Knowledge/TCK), a new knowledge called Technological Pedagogical and Content Knowledge (TPACK). Technological, Pedagogical, Content, Knowledge (TPCK) in vocational education as a framework for the effective use of technology in vocational education learning [37].

The rationale for the PjBL instructional model with the TPACK approach developed is to improve the digital competence of prospective vocational teachers based on several key factors. First, PjBL facilitates the direct use of digital technology in project implementation, so that prospective vocational teachers are forced to interact with various digital tools and platforms [38]. It provides an opportunity for them to learn and master relevant technology in real contexts. Second, the PjBL instructional model encourages collaboration and communication through digital media [39], such as the use of project management software, online collaboration tools, and digital presentation applications, all of which improve digital skills. Third, PjBL instrucional model emphasizes problem solving and creative thinking [40], which requires access to and analysis of digital information, as well as the use of special software to complete complex tasks. Fourth, prospective vocational teachers will be more familiar with integrating technology into their teaching strategies [41], which in turn increases their readiness to adopt digital technology in teaching practice. The instructional process (syntax) of PjBL instructional model with TPACK approach can be seen in Table 1.

**Table 1.**
Syntax of the TPACK approach PjBL model.

| Phase | Activity |
|---|---|
| Phase 1: Essential questions | • Student characteristics analysis (PK)<br>• Formulating learning objectives (PK)<br>• Conducting a review of the media that has been used (TPK)<br>• Media needs analysis (TK)<br>• Analyzing essential concepts (CK)<br>• Analyzing vocational content teaching (PCK)<br>• Determining themes/Topics (TPK) |
| Phase 2 : Design | • Planning projects<br>• Preparing a learning plan for integrating technology |

*Edelweiss Applied Science and Technology*
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| Phase | Activity |
|---|---|
| | and digital media in the vocational field (TCK)<br>• Making a schedule |
| Phase 3: Preparation of teaching materials | • Creating a concept map of teaching materials (CK)<br>• Compiling teaching materials<br>• Compiling practice questions<br>• Creating student worksheets |
| Phase 4: Product development | • Creating product<br>• Providing feedback/review<br>• Revision 1 |
| Phase 5: Product presentation | • Peer teaching product usage (integration of digital-based technology and media) (TPACK)<br>• Assessment<br>• Feedback on peer teaching of the product<br>• Revision 2 |
| Phase 6: Evaluation and reflection | • Follow-up plan<br>• Review of learning experiences<br>• Best practice/meaningful learning |

## 3. Methods

*3.1. Setting and Participants*

The study setting is two universities in Yogyakarta (Universitas Negeri Yogyakarta and Universitas Sarjanawiyata Tamansiswa). This study focused on vocational education for prospective teachers in higher education. The course studied is the digital transformation of learning media. There are two groups, namely experimental and control groups. The study sample used was 102 prospective vocational education teachers, including 45 prospective vocational teachers in the control group and 57 prospective vocational teachers in the control group. This study sample was selected using a cluster random sampling method.

*3.2. Design of Study*

This research uses a quasi-experimental study using a control group with a pre and post-test design (see Table 2. The data was tested with the independent sample t-tests using SPSS software.

**Table 2.**
Quasi-experimental design.

| Group | Pre-test | Treatment | Post-test |
|---|---|---|---|
| Experimental | $A_1$ | $X_1$ | $A_2$ |
| Control | $B_3$ | $X_2$ | $B_4$ |

**Note:** $A_1$ and $B_1$ are pretest of digital competence ; $A_2$ and $B_4$ are post-test of digital competence; $X_1$ : PjBL instructional model with TPACK Approach; and $X_2$ : Conventional instructional model.

*3.3. Instrument of Digital Competence*

The digital competency dimensions and indicators are shown in Table 3. The digital competency scale instrument for data collection used a Google Form.

*Edelweiss Applied Science and Technology*
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**Table 3.**
Dimensions and indicators of digital competence.

| Dimensions | Indicators |
|---|---|
| Professional engagement | Communication; collaboration; continuous improvement of digital professionalism |
| Digital resources | Choosing digital resources, developing and editing digital content, along with organizing, safeguarding, and distributing digital resources. |
| Learning process | Teaching; collaborative learning; independent learning |
| Evaluation | Analyze evidence; assessment strategy; feedback and planning |
| Empowering students | Making a difference; personalization actively engages students |
| Facilitating student's digital competence | Information and media literacy; creation of digital content; digital communication and teamwork; digital problem-solving skills; responsible digital usage. |

The instrument of digital competence was assessed by eight expert validators. After being tested for validity, it was tested for reliability. The final results of the digital competency test questions are thirty questions.

*3.4. Data analysis*

The study used SPSS software to analyse the digital competence scores of the two groups. The independent t-test was used to compare the scores of two groups after implementing the PjBL with TPACK approach to prospective vocational teachers for parametric data.

Before conducting the independent t-test, prerequisite analysis tests were carried out, namely normality (Table 4) and homogeneity tests (see Table 5). The data normality test was carried out using the *Shapiro-Wilk* Test for the control group because the amount of data concerned was less than fifty, while the *Kolmogorov-Smirnov* Test was for the experimental group [42].

**Table 4.**
Result of normality test.

| Group | Test | N | Normality test | | | Conclusion |
|---|---|---|---|---|---|---|
| | | | Statistics | df | Sig. | |
| Control | Pre-test | 45 | 0.975 | 45 | 0.438 | Normal |
| | Post-test | 45 | 0.064 | 45 | 0.200 | Normal |
| Experimental | Pre-test | 57 | 0.107 | 57 | 0.099 | Normal |
| | Post-test | 57 | 0.111 | 57 | 0.055 | Normal |

The hypotheses of independent t-test are: H0: there is no significant difference between the post-test average score of the experimental and control group and Ha: there is a significant difference between the post-test average score of the experimental and control group. The conclusion can be drawn that H0 is accepted if the sig value. < 0.05 while H0 is rejected if the value is sig. > 0.05 [43].

## 4. Results

*4.1. Result*

The digital competency scores of prospective vocational school teachers in the experimental group applying PjBL instructional model with TPACK approach showed an increase from the initial score of 75.96 to 79.19, while in the control group without treatment there was a decrease (see Figure 1).

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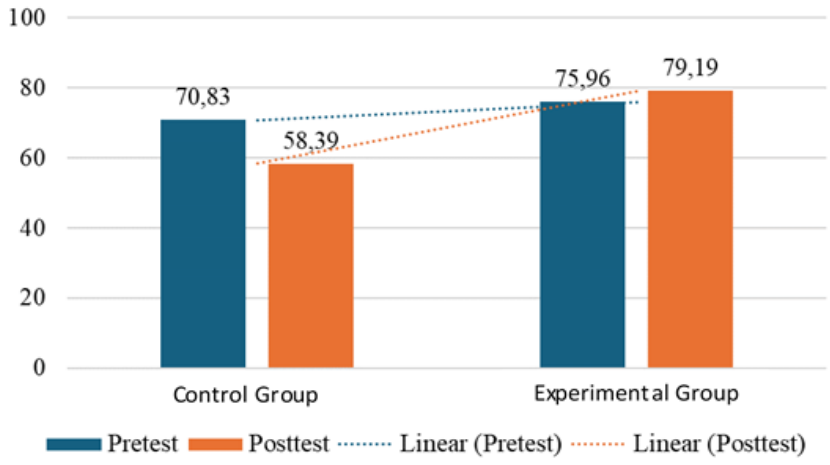


**Figure 1.**
Result of digital competence score of the experimental and the control groups

From Table 5, sig. Levene Test for Equality of Variances 0.623 > 0.05. It means that the data between two group are homogeneous (Sujarweni, 2014). Meanwhile sig. (2-tailed) with equal variances assumed of 0.000 < 0.050, then as is the basis for decision-making for the independent sample t-test. Hypothesis H0 is rejected and Ha is accepted. Thus, it was concluded that there was a significant difference between the post-test average score of the experimental and the control groups.

**Table 5.**
Result of independent-t test from post-test data.

| **Levene's test for equality of variances** | | | **t-test for equality of means** | | | | |
|---|---|---|---|---|---|---|---|
| **Data** | **F** | **Sig** | **t** | **df** | **Sig (2-tailed)** | **Mean difference** | **Std. error difference** |
| Equal variances assumed | 0.243 | 0.623 | -14,813 | 100 | 0.000 | -20,80408 | 1,40447 |
| Equal variances not assumed | | | -15,073 | 99.178 | 0.000 | -20,80408 | 1,38019 |

## 5. Discussion

Digital competency is key in every stage of project-based learning [44], [45]. The digital competence of prospective vocational teachers shows that the PjBL instructional model with the TPACK approach has a positive impact on enhancing their competencies (see Table 6). This research also shows that the PjBL instructional model with TPACK approach has a positive impact on TPACK components. The framework of the PjBL with TPACK approach can be seen in Figure 2. It indicates that this model can enhance students' mastery as prospective teachers of learning content, pedagogical knowledge, and skills in integrating technology into learning better than conventional instuctional models [46]. The implementation of the PjBL instructional model has a positive impact on enhancing students' digital literacy skills [47], [48].

*Edelweiss Applied Science and Technology*
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*DOI: 10.55214/25768484.v8i5.1696*

**Table 6.**
Contribution of syntax to indicator of digital competence.

| Syntax/Instructional process | Indicator of digital competence |
|---|---|
| Phase 1: Essential questions | Professional engagement, facilitating students' digital competence, empowering students, learning process |
| Phase 2: Design | Professional engagement, digital resources, empowering students, facilitating students' digital competence |
| Phase 3: Preparation of teaching materials | Professional engagement, facilitating students' digital competence, digital resources |
| Phase 4: Product development | Learning process, evaluation, digital resources |
| Phase 5: Product presentation | Learning process, empowering students, digital resources |
| Phase 6: Evaluation and reflection | Learning process, digital resources, facilitating students' digital competence, evaluation |

This study supports the urgency of developing students' digital literacy through technology-based and project-based approaches [49]. The integration of technology in education, as well as the application of project-based methods, is very effective in enhancing digital compentence [44]. This study continues and deepens these findings by identifying more specific strategies for advancing digital skills, especially in the context of vocational education.

The findings of this research have significant implications, both theoretically and practically. Some of the theories or findings that are strengthened include: 1) the effectiveness of this instructional model in enhancing the digital competence of prospective vocational teachers, 2) the importance of developing the digital competence of prospective vocational teachers continuously in the context of learning certain materials or courses, 3) the effectiveness of enhancing the digital competence of prospective vocational teachers by giving responsibility for learning tasks, such as providing projects to create learning media for vocational education. The practical implications of implementing the PjBL instructional model with the TPACK approach include: 1) educators have the opportunity to apply the model in learning media to enhance the digital competence of prospective vocational teachers, 2) educators can enhance the digital competence of prospective vocational teachers through each course they teach, by setting indicators that are relevant to the material, 3) educators can enhance the competence of prospective vocational teachers by carrying out project activities in creating learning media and implementing them in vocational education environments. Enhancing teachers' digital competence can be enhanced through active implementation of methodologies [50].

**Figure 2.**
QR code from framework of PjBL instructional model with TPACK approach.

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## 6. Conclusion

The PjBL instructional model with TPACK approach has been applied to enhance the digital competence of prospective vocational teacher. The results of the test of the difference in average digital competence scores between two groups showed that both were significantly different. For further researchers, they can follow the development stages according to the selected model, refer to the philosophical, psychological, sociological, and pedagogical foundations in product development, and adapt it to prospective teacher characteristics and subject matter.

## 7. Recommendations

Further research is recommended to compare the effectiveness of the Project Based Learning (PjBL) instructional model with other instructional models with TPACK approach such as Blended Learning or Flipped Classroom to enhance digital competence of prospective teachers. Researchers can also involve samples from universities in other regions or even other countries to investigate whether similar results are found in different contexts.

## 8. Limitations

In the research and development process, several limitations were also identified as follows: a) at the stage of comprehensive product testing, the PjBL model with the TPACK framework that was developed was only applied in two universities in the Yogyakarta area, and could not be expanded to other areas; b) the number of students who were the subjects of the research was still limited, both in the control and the experimental groups, with incomplete participation in the learning and/or evaluation process, which could potentially affect the research results; and c) data collected through questionnaires to measure digital competencies are highly dependent on the honesty and sincerity of respondents in filling out the questionnaire.

## Institutional Review Board Statement:

The Ethical Committee of the Universitas Negeri Yogyakarta Indonesia has granted approval for this study on January 1, 2024 (Ref. No. 'T/55/UN34.9/KP.06.07 /2023).



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