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# Development of Smart Andragogical LMS–Padlet Based on Behavioral Learning Analytics in the Course of Student Understanding and Automotive Indonesia's Teacher Professional Education (PPG) Program Learning

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**ABSTRACT**

This research is motivated by the suboptimal Technological Pedagogical Content Knowledge (TPACK) competency of Automotive Professional Teacher Education (PPG) students in designing meaningful, contextual, and technology-integrated learning. The use of Learning Management Systems (LMS) in the Student Understanding and Learning course is still limited to material distribution and assignment collection, thus not supporting data-based reflective, collaborative, and adaptive learning. This condition encourages the need to develop an andragogy-based digital learning system that utilizes Behavioral Learning Analytics to improve students' TPACK competency.

This study aims to develop a valid, practical, and effective Smart Andragogical LMS–Padlet based on Behavioral Learning Analytics in improving the TPACK competency of Automotive PPG students. The research method used Design and Development Research (DDR) which includes the stages of model development, model validation, and model implementation. The development stage includes needs analysis, andragogy-based LMS architecture design, Padlet integration as a collaborative reflection medium, and the development of a learning analytics dashboard. Data collection was carried out through document review, interviews, questionnaires, TPACK pretest–posttest, and analysis of LMS and Padlet activity logs. Data were analyzed using thematic analysis, descriptive statistics, N-Gain test, and learning analytics analysis. The results showed that the developed product met the criteria of being valid, practical, and effective. The product consists of an andragogy-based LMS, a Padlet collaborative reflection space, a learning analytics dashboard, TPACK-based learning tools, and an evaluation instrument. Product implementation increased the average TPACK competency of students from 61.83 to 86.47 with an N-Gain value of 0.65 (moderate category). The student engagement level reached 93.86% (very high category), while the analytics dashboard was able to monitor the development of student competencies and

engagement in real time, thus supporting data-based learning decision-making.



## Introduction

The Teacher Professional Program (PPG) is a national strategic policy in preparing professional teachers who are adaptive to developments in science, technology, and the characteristics of 21st-century students and is aligned with the fourth Asta Cita which emphasizes strengthening the development of superior human resources through science and technology-based educational transformation. In the context of teacher education, PPG functions not only as a certification program, but as a learning ecosystem that forms reflective, professional, and transformative pedagogical competencies through the integration of meaningful learning experiences. The Technological Pedagogical Content Knowledge (TPACK) framework is an important foundation in preparing prospective teachers who are able to integrate pedagogy, content, and technology contextually in vocational learning.(Baran, 2019; Mishra & Koehler, 2006; Voogt et al., 2013)However, various studies show that the mastery of TPACK by prospective teacher students is still at the conceptual level and has not been optimally implemented in authentic, student-centered technology-based learning designs.(Bueno-Alastuey & Kleban, 2018; Dong, 2015; Durdu & Dag, 2017).

The results of the needs analysis for the Student Understanding and Learning course in the Automotive PPG show that the use of the LMS is still oriented towards distributing materials and collecting assignments, not yet being utilized as a reflective, collaborative, and adaptive learning space based on data. Students tend to focus on preparing learning tools administratively, while the in-depth analysis of the characteristics of vocational high school students, the selection of contextual learning strategies, and the integration of learning technology have not shown a complete integration of TPACK. This condition is in line with the findings of previous research which stated that digital learning without appropriate pedagogical design will only transfer conventional learning patterns to online platforms without improving the quality of the learning process.(Maknun, 2022; Tondeur et al., 2020; Valtonen et al., 2020)In fact, from an andragogical perspective, PPG students as adult learners need a learning environment that is flexible, collaborative, experience-based, and relevant to their professional needs.(Eutsler, 2022; Jin & Harp, 2020)

The development of learning analytics provides an opportunity to transform LMS into an intelligent learning system that is able to record, analyze, and visualize student learning behavior as a basis for providing adaptive feedback.(Gašević et al., 2015; Kaliisa et al., 2024; Muslim et al., 2023; Siemens & Baker, 2012; Viberg et al., 2018). Through the Behavioral Learning Analytics approach, student interaction data such as participation intensity, reflection depth, discussion patterns, and involvement in completing case studies can be used to map the development of pedagogical competence more comprehensively. The integration of collaborative platforms such as Padlet in an LMS allows students to construct knowledge socially through visual representations, case-based discussions, and

systematically documented pedagogical reflections, which have been proven to increase engagement and the quality of learning in higher education [18]–[20].

Based on these problems, innovation in learning systems is needed that is not only conceptual but operational, implementative, and data-based to strengthen the TPACK of Automotive PPG students. This study offers the development of Smart Andragogical LMS–Padlet based on Behavioral Learning Analytics as a digital learning ecosystem that integrates the principles of andragogy, reflective learning, visual collaboration, and analysis of student learning behavior. So this study aims to develop a Smart Andragogical LMS–Padlet based on Behavioral Learning Analytics that is valid, practical, and effective in improving the TPACK competency of PPG students in the automotive field of study. Meanwhile, the novelty of this study lies in the integration of andragogy-based LMS design with Padlet as a collaborative knowledge construction space and dashboard analytics as an adaptive feedback system specifically developed for the context of the Student Understanding and Learning course in Automotive PPG, which has not been available in the form of valid, practical, and effective learning products in strengthening students' TPACK competencies.

## Method

This research uses the Design and Development Research (DDR) approach as proposed by Richey and Klein (2007), which emphasizes the systematic process of designing, developing, and evaluating learning products. The development model in this research uses the Design and Development Research (DDR) approach, which includes three main stages: model development, model validation, and model implementation (model use).

The development phase begins with a needs analysis to identify the characteristics of PPG students as adult learners, the use of LMS in the Understanding of Students and Learning course, the level of TPACK competency, and the need for technology-based reflective and collaborative learning. The results of the analysis are used to design the Smart Andragogical LMS, integrate Padlet as a collaborative reflection space, develop a Behavioral Learning Analytics dashboard to monitor student engagement and learning activities, and compile learning tools and TPACK measurement instruments. Next, the model is validated through expert judgment involving experts in learning technology, vocational pedagogy, and Automotive PPG materials, as well as user validation through Focus Group Discussions (FGD) with PPG lecturers and readability and implementation tests by students to assess validity, practicality, and obtain feedback for improvements.

The implementation stage was carried out through a limited trial in the course of Understanding Students and Learning, which included orientation on the use of Smart Andragogical LMS–Padlet, case study-based learning of SMK students' characteristics, collaborative discussions and pedagogical reflections through Padlet, and the preparation of learning designs by students to evaluate the effectiveness of the model in improving TPACK competencies. The subjects of the study were PPG Daljab students in the field of Automotive Engineering at the State University of Malang who took the course of Understanding Students and Learning, totaling ±36 students in one class.

**Table 1 Data Collection Techniques and Instruments**

| Stage | Activity Objectives | Data source | Data collection technique | Instrument |
|---|---|---|---|---|
| **Model Development** | Learning needs analysis | RPS, modules, LMS PPG | Document review | Document review sheet |
| | Actual learning analysis | PPG lecturers & students | Interview & observation | Interview guidelines & observation sheets |
| | TPACK competency needs analysis | Literature & students | Questionnaire | TPACK Questionnaire |
| | LMS–Padlet system design | Results of needs assessment & literature review | Content analysis | Model component analysis sheet |
| **Model Validation** | Internal validation (expert review) | Learning technology expert, vocational pedagogical expert, PPG material expert | Expert judgment | Expert validation sheet |
| | External validation (practicality) | Lecturers & PPG students | FGD & questionnaire | User practicality questionnaire |
| **Model Use** | Model effectiveness test | PPG Students | Pretest–posttest, questionnaire, learning analytics | TPACK test, engagement questionnaire, LMS activity log |

**Table 2 Data Analysis Techniques**

| No | Data Types | Data source | Analysis Techniques | Purpose of Analysis | Decision Criteria |
|---|---|---|---|---|---|
| 1 | Qualitative data from interviews, observations, and FGDs | PPG lecturers, PPG students, practitioners | Thematic analysis | Identifying learning needs, refining LMS design, and evaluating implementation | The themes that emerge are used as the basis for product revisions. |
| 2 | Document review data (RPS, modules, LMS activities) | PPG learning documents | Content analysis | Knowing the suitability of learning devices | Level of suitability of learning components |
| 3 | Expert validation data | Learning technology expert, vocational pedagogical expert, material expert | Descriptive statistics (mean score) | Determining the level of product validity | • 3.25–4.00 = Very valid<br>• 2.50–3.24 = Valid1,<br>• 75–2.49 = Less valid<br>• <1.75 = Invalid |
| 4 | User convenience data | PPG lecturers and students | Descriptive statistics percentage | Find out the level of ease of use of LMS–Padlet | • ≥ 85% = Very practical<br>• 70–84% = Practical |

| No | Data Types | Data source | Analysis Techniques | Purpose of Analysis | Decision Criteria |
|---|---|---|---|---|---|
| | | | | | • 55–69% = Quite practical<br>• <55% = Not practical |
| 5 | Effectiveness data (TPACK pretest–posttest) | PPG Students | N-Gain Test | Knowing the improvement of TPACK competency | • ≥ 0.70 = High<br>• 0.30–0.69 = Moderate<br>• <0.30 = Low |
| 6 | Student engagement data | LMS Log & Padlet activity | Learning analytics & descriptive statistics | Analyzing student engagement in learning | High if participation ≥ 75% of activity indicators |
| 7 | System usability data | PPG Students | SUS score / usability questionnaire (descriptive) | Knowing the level of system usability | ≥ 68 = Good (acceptable) |

## Results and Discussion

### 1. Needs Analysis

The needs analysis stage was conducted to obtain a comprehensive picture of the learning conditions in the Student Understanding and Learning course of the Automotive Engineering PPG Program, State University of Malang. The results of document review, observation, and interviews indicate that the LMS used has supported the distribution of materials, information delivery, and assignment collection, but is still oriented towards administrative functions. Learning has not fully supported reflective, collaborative, adaptive activities, or learning behavior analysis, so that the development of students' Technological Pedagogical Content Knowledge (TPACK) competencies has not been optimal. In addition, students still tend to compile learning tools administratively with an unintegrated integration of pedagogy, content, and technology.

Interviews with lecturers revealed the need for a system capable of continuously monitoring student engagement, reflection quality, discussion patterns, and competency development, as well as providing early warnings for students with low participation. Meanwhile, questionnaire results indicated that students desired an LMS that was more interactive and flexible, provided space for collaboration and pedagogical reflection, and displayed real-time visualizations of competency development. These findings formed the basis for the development of the Smart Andragogical LMS–Padlet based on Behavioral Learning Analytics as a digital learning ecosystem that supports data-driven learning and strengthens TPACK competencies.

**Table 1 Results of Student Needs Analysis for Smart Andragogical LMS–Padlet**

| No | Analysis Aspects | Percentage (%) | Category |
|---|---|---|---|
| 1 | The need for a more interactive LMS | 92.4 | Very high |
| 2 | The need for a Padlet-based reflection space | 90.8 | Very high |
| 3 | TPACK competency monitoring | 94.1 | Very high |
| 4 | Behavioral Learning Analytics Dashboard | 91.7 | Very high |
| 5 | Adaptive feedback from lecturers | 93.5 | Very high |
| 6 | Visualization of learning progress | 89.6 | Tall |

| | | |
|---|---|---|
| **Average** | **92.02** | **Very high** |

The analysis showed that students needed an LMS that not only provided materials but also monitored the development of TPACK competencies, learning activities, participation quality, and provided data-driven learning recommendations. Furthermore, technological readiness was deemed adequate because all students already had digital devices and the PPG LMS was used routinely. Therefore, development focused on integrating Padlet and Behavioral Learning Analytics without building a new system.

**2. Smart Andragogical LMS Design – Padlet Based on Behavioral Learning Analytics**

The design phase is the process of translating the results of the needs analysis into conceptual and technical designs for the Smart Andragogical LMS – Padlet based on Behavioral Learning Analytics. The system is designed as an adaptive digital learning environment that not only supports the distribution of materials, but also facilitates adult learning, reflective collaboration, and continuous analysis of learning behavior. The design refers to the Design and Development Research (DDR) approach by integrating three main components: andragogical principles, Padlet as a medium for collaboration and pedagogical reflection, and Behavioral Learning Analytics to monitor student engagement, interaction patterns, and the development of TPACK competencies in real time.

The system architecture consists of four layers: the user layer, the learning layer, the analytics layer, and the feedback layer. Students study the material, complete case studies, discuss and reflect through Padlet, and develop TPACK-based learning plans. Lecturers facilitate learning and provide feedback based on dashboard analysis. The system records access frequency, learning duration, discussion participation, reflection quality, assignment submission accuracy, and competency development, then presents these visualizations as a basis for data-driven learning decisions.

**Table 2 Components of Smart Andragogical LMS–Padlet**

| NO | COMPONENT | FUNCTION |
|---|---|---|
| 1 | Learning Management System (LMS) | The main media for implementing learning |
| 2 | Padlet | Pedagogical reflection space and visual collaboration |
| 3 | Behavioral Learning Analytics Dashboard | Monitoring student learning activities and progress |
| 4 | TPACK Assessment | Measuring students' TPACK competencies |
| 5 | Case-Based Learning | Providing authentic case studies of learning in vocational schools |
| 6 | Adaptive Feedback | Provide feedback based on learning behavior |

The Smart Andragogical LMS design – Padlet was developed with a simple and consistent menu structure to make it easy for students to access learning outcomes, course agendas, learning progress, the Padlet discussion room, and the analytics dashboard. Padlet is integrated as a pedagogical reflection space for uploading case analyses, discussions, providing feedback, and documenting learning experiences, while also serving as the primary source of Behavioral Learning Analytics data. The developed dashboard presents

indicators of chance of success, prediction quality, grade distribution, historical learning records, learning achievement development, and student competency mapping in the form of visualizations that support lecturers in conducting early interventions and help students monitor their competency development independently through data-driven decision-making.

**Table 3 Behavioral Learning Analytics Dashboard Feature Design**

| No | Feature | Information Displayed | Benefit |
|---|---|---|---|
| 1. | Chance of Success | Prediction of learning success | Early detection of at-risk students |
| 2. | Prediction Quality | System prediction accuracy | Analytical quality evaluation |
| 3. | Student Engagement | Student participation level | Engagement monitoring |
| 4. | Historical Learning Record | History of learning activities | Evaluation of competency development |
| 5. | Course Skills | Expected competencies | Mapping learning outcomes |
| 6. | Student Skills | Actual student competencies | Identify competency gaps |

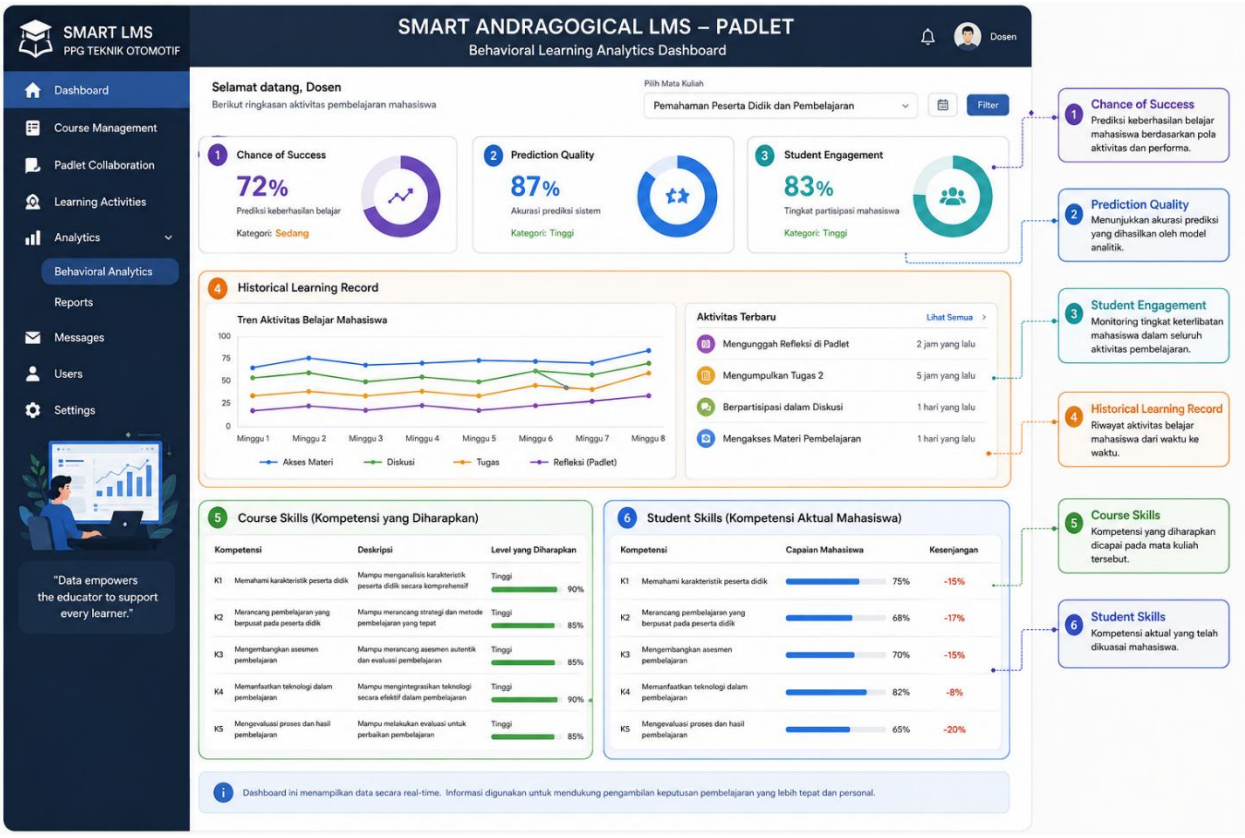


**Figure 1 Behavioral Learning Analytics Dashboard Features**

Overall, the design phase resulted in a system design that integrates the principles of andragogy, Padlet-based collaborative learning, and Behavioral Learning Analytics in a single digital learning platform. This design not only addresses user needs identified in the previous phase but also serves as the basis for the product development process in the next phase. With this design, the Smart Andragogical LMS–Padlet is expected to transform the PPG LMS into a more adaptive, reflective, collaborative, and data-driven learning environment, thereby supporting the improvement of PPG students' TPACK competencies in the automotive field. The next phase is the product development process, validation by experts, and model revision until a product is obtained that is feasible to be implemented.

### 3. Product Development and Validation

The development stage of the Smart Andragogical LMS–Padlet includes the development of a CPL-based Learning Management System (LMS), RPS, and case studies containing digital materials, collaborative activities, pedagogical reflections, and TPACK-based assessments. The system is integrated with Padlet as a collaboration and reflection space, while all student activities are recorded through Behavioral Learning Analytics. The developed dashboard visualizes access frequency, participation, learning duration, assignment accuracy, discussion quality, TPACK development, and provides a learning success prediction feature. To support implementation, LMS and Padlet guidelines, andragogy-based RPS, reflective learning scenarios, TPACK instruments, student engagement instruments, and dashboard interpretation guides were also developed so that the system can be applied consistently. Before being implemented with students, the developed product first went through an internal validation process (expert judgment). Validation was carried out by three groups of experts, namely learning technology experts, vocational pedagogy experts, and PPG Automotive material experts. The assessment focused on the suitability of the andragogy concept, the quality of the interface design, the integration of the LMS with Padlet, the functionality of the learning analytics dashboard, and the suitability of the content to the PPG learning outcomes.

**Table 4 Expert Validation Results**

| No | Rated aspect | Average Score | Category |
|---|---|---|---|
| 1. | The suitability of the concept of andragogy | 3.82 | Very Valid |
| 2. | LMS interface design | 3.78 | Very Valid |
| 3. | LMS–Padlet Integration | 3.85 | Very Valid |
| 4. | Behavioral Learning Analytics Dashboard | 3.74 | Very Valid |
| 5. | Compliance of material with CPL PPG | 3.87 | Very Valid |
| 6. | Ease of system navigation | 3.80 | Very Valid |
| | **Average** | **3.81** | **Very Valid** |

Validation results showed that all aspects achieved an average score above 3.25, thus categorizing them as highly valid. The validators assessed that the Smart Andragogical LMS–Padlet design aligns with adult learning principles, has an easy-to-understand navigation flow, and integrates learning activities with student learning behavior analysis. However, several suggestions for improvement were provided as part of the product refinement process prior to implementation.

**Table 5 Validator Input and Revision Follow-up**

| No | Validator | Input | Follow-up |
|---|---|---|---|
| 1. | Learning Technology Expert | Dashboard needs to be more informative | Add visual indicators and learning progress graphs |
| 2. | Vocational Pedagogy Expert | Case studies need to be more contextual | Adding case studies of learning in Automotive Vocational Schools |
| 3. | PPG Material Expert | TPACK instruments need to be emphasized | Refining TPACK assessment indicators |

All validator input was incorporated into the product revision process. Revisions included improving the interface, simplifying the navigation menu, adding system user guides, refining the TPACK assessment instrument, and optimizing the visualization of the learning analytics dashboard. Furthermore, the developers added an automatic notification feature for students with low participation rates, allowing lecturers to provide early support.

**4. Product Implementation**

The implementation phase is the initial testing of the Behavioral Learning Analytics-based Smart Andragogical LMS–Padlet that has gone through the development and validation process. The trial was conducted on a limited basis on 36 PPG Automotive Engineering students taking the Student Understanding and Learning course to evaluate the implementation, practicality, and effectiveness of the system in improving Technological Pedagogical Content Knowledge (TPACK) competencies. Before the learning began, students attended an orientation on the use of the LMS, Padlet as a collaborative reflection space, and the learning analytics dashboard to ensure all participants understood the learning flow and the utilization of each feature.

The learning process is implemented through authentic case studies of vocational high school student characteristics that are analyzed individually and collaboratively through Padlet, then developed into a TPACK-based learning design. All student activities are automatically recorded in the LMS and processed using Behavioral Learning Analytics. The effectiveness of the implementation is evaluated through a TPACK competency pretest–posttest using validated instruments, while the level of student engagement is measured through analysis of LMS activity logs, interactions on Padlet, and learning engagement questionnaires. The evaluation results are used to assess the success of the implementation and serve as a basis for improving the data-driven learning system.

**Table 6 Results of the TPACK Competency Pretest and Posttest**

| No | Component | Mark |
|---|---|---|
| 1. | Number of students | 36 |
| 2. | Pretest average | 61.83 |
| 3. | Posttest average | 86.47 |
| 4. | Score improvement | 24.64 |

| No | Component | Mark |
|---|---|---|
| 5. | N-Gain | 0.65 |
| 6. | Category | Currently |

The results in Table 6 show that the average TPACK competency of students increased after participating in learning using Smart Andragogical LMS–Padlet. The average pretest score of 61.83 increased to 86.47 in the posttest, with an N-Gain value of 0.65, which is in the moderate category. This increase indicates that the developed system has the potential to improve students' ability to integrate aspects of technology, pedagogy, and learning content better than before implementation. To provide a visual illustration of the increase in student competency, the pretest and posttest results can be presented in the following bar chart.

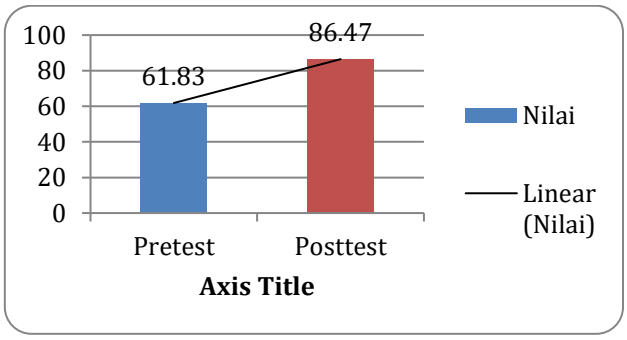


**Figure 2 Pretest and posttest graph**

In addition to improving TPACK competency, the system's implementation also demonstrated a high level of student engagement. Based on an analysis of LMS and Padlet activity logs, the majority of students actively participated in discussions, uploaded pedagogical reflections, and completed assignments on time.

**Table 7 Student Engagement Results**

| No | Indicator | Percentage (%) | Category |
|---|---|---|---|
| 1. | LMS access frequency | 95.3 | Very high |
| 2. | Padlet discussion participation | 93.8 | Very high |
| 3. | Accuracy of assignment collection | 97.2 | Very high |
| 4. | Pedagogical reflection activities | 90.4 | Very high |
| 5. | Student interaction | 92.6 | Very high |
| | **Average** | **93.86** | **Very high** |

These results demonstrate that the implementation of the Smart Andragogical LMS–Padlet is able to create a more active learning environment than conventional LMS-based learning. The integration of Padlet as a collaborative reflection space encourages students to exchange ideas more frequently, provide feedback on each other's work, and reflect on the learning experiences gained during lectures. These activities are directly recorded in the Behavioral Learning Analytics dashboard, providing lecturers with a more comprehensive picture of each student's progress.

### 4.5 Product Evaluation

The evaluation phase is the final stage in the development of the Behavioral Learning Analytics-based Smart Andragogical LMS–Padlet, which aims to assess the overall quality of the product before recommending it for wider implementation. The evaluation is carried out comprehensively through analysis of expert validation results, user practicality tests, system usability, implementation effectiveness, and monitoring results obtained through the Behavioral Learning Analytics dashboard. The evaluation process is not only focused on the technical quality of the system, but also on the extent to which the product is able to meet the needs of PPG students as adult learners and support the continuous strengthening of Technological Pedagogical Content Knowledge (TPACK) competencies.

Formative evaluation was conducted throughout the product development process. All input provided by validators and users was systematically analyzed to determine areas of the product that needed improvement. Based on internal validation results, experts generally stated that the Smart Andragogical LMS–Padlet met andragogical principles, had a clear learning structure, and was able to integrate the LMS, Padlet, and learning analytics dashboard into a single, interconnected system. However, several components still needed improvement, particularly in dashboard visualization, system navigation, and the presentation of student competency development indicators to make them more easily understood by users.

The input provided by the validators was then implemented through several revisions. The developers simplified the menu structure so students could access learning activities more quickly. The dashboard display was also improved by adding visual indicators in the form of competency development graphs, student engagement percentages, and predicted learning success (chance of success), making the information displayed more communicative. Furthermore, an automatic notification system was developed to alert students with low participation rates or late assignment submissions.

After the revision process was completed, the next stage was a practicality evaluation through a limited trial with teaching faculty and PPG students. This evaluation aimed to determine the system's ease of use, clarity of navigation, ease of access to materials, the effectiveness of using Padlet as a reflection tool, and the usefulness of the Behavioral Learning Analytics dashboard in supporting the learning process.

**Table 8 Results of Product Practicality Test**

| No | Rated aspect | Percentage (%) | Category |
|---|---|---|---|
| 1. | Ease of use of LMS | 94.6 | Very Practical |
| 2. | Navigation clarity | 92.8 | Very Practical |
| 3. | Padlet's ease of use | 95.3 | Very Practical |
| 4. | Learning Analytics Dashboard | 91.7 | Very Practical |
| 5. | Clarity of material | 94.1 | Very Practical |
| 6. | Ease of interaction | 93.4 | Very Practical |
| | **Average** | **93.65** | **Very Practical** |

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The evaluation results showed that all aspects achieved a score above 85%, making it categorized as very practical. Students stated that the system was easy to use, even for their first time using the learning analytics dashboard. Padlet was deemed to improve the quality of discussions by providing a space for students to express their reflections more freely and in a documented manner. Lecturers found the dashboard very helpful in quickly monitoring student learning progress without having to check individual LMS activities.

In addition to practicality testing, the study also evaluated the system's usability using the System Usability Scale (SUS) as outlined in the research methodology. This evaluation is crucial to ensure that the developed system is truly user-friendly for users of varying technological abilities.

**Table 9 Results of System Usability Evaluation (SUS)**

| No | Indicator | Mark |
|---|---|---|
| 1. | Average SUS score | 84.7 |
| 2. | Category | Excellent |
| 3. | Acceptability | Acceptable |

The SUS score of 84.7 indicates that the Smart Andragogical LMS–Padlet has an excellent level of usability. Users considered the system easy to learn, did not require a long adaptation time, and was able to support learning activities without causing significant difficulties. These results indicate that the developed interface design has met the principles of user-centered design and is able to provide a positive learning experience for both students and lecturers. To clarify the results of the practicality evaluation, the data can be visualized using the following bar chart.

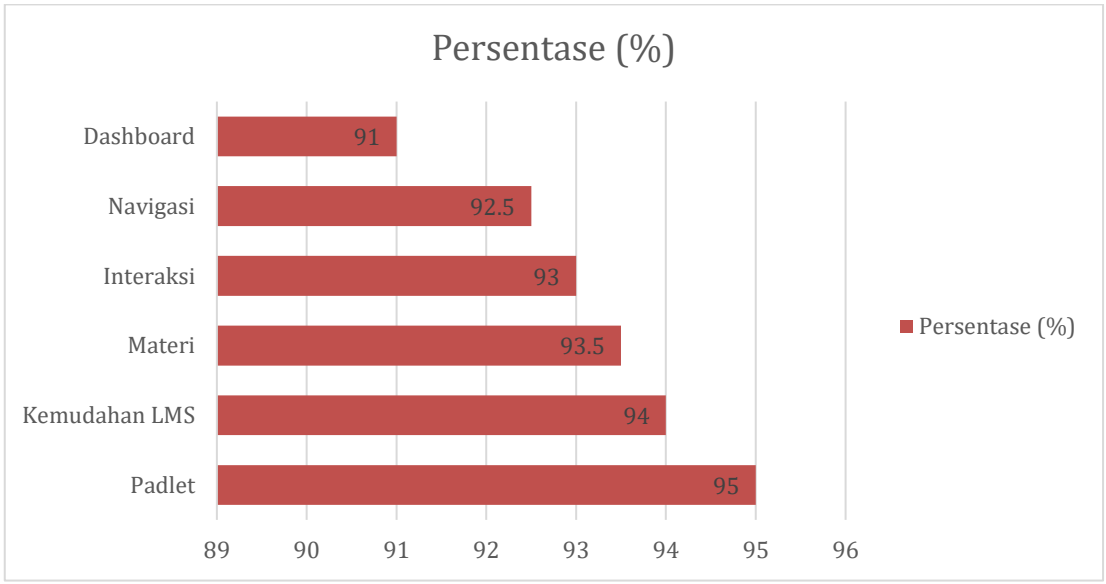


**Figure 3 Graph of Practicality Evaluation Results**

Evaluation was also conducted on data generated by the Behavioral Learning Analytics dashboard. Based on monitoring results during implementation, the system was able to automatically record all student activities, including login frequency, study duration, Padlet discussion intensity, assignment completion, and TPACK competency development. This information was visualized in the form of individual and class progress graphs so that

lecturers could more quickly identify students who needed academic assistance. This feature is one of the product's main advantages because it can support data-driven learning decision-making, which was not available in the previous PPG LMS.

## Discussion

### Technological Pedagogical Content Knowledge (TPACK

The results of the study indicate that the development of Smart Andragogical LMS–Padlet based on Behavioral Learning Analytics has a positive impact on improving the Technological Pedagogical Content Knowledge (TPACK) competency of students in the Professional Teacher Program (PPG) in the field of Automotive Engineering. Based on the implementation results, there was an increase in the average TPACK score from 61.83 in the pretest to 86.47 in the posttest with an N-Gain value of 0.65 (moderate category). In addition, the level of student engagement during the learning process reached an average of 93.86% with a very high category. These findings indicate that the integration of LMS, Padlet, and Behavioral Learning Analytics is able to create a more active, reflective, and oriented learning experience to the needs of adult learners compared to conventional LMS-based learning.

The improvement in TPACK competency did not occur by chance, but rather was a logical consequence of a learning design that integrated three main components: digital technology, pedagogical strategies, and learning content.Mishra & Koehler, (2006)TPACK is a form of integrated knowledge that allows a teacher to harmoniously combine technology, pedagogy, and teaching materials in the learning process. In this study, students not only studied theories about student characteristics, but also directly designed digital learning tools, discussed real-life cases, and conducted pedagogical reflections using Padlet. Thus, mastery of TPACK develops through authentic experiences that involve direct learning practices, not just conceptual understanding.

The results of this study strengthen the viewAnderson, (2011); and Knowles et al., (2015)which states that TPACK development will be more effective if carried out through practice-based learning activities (learning by designing). PPG students in this study actively designed learning strategies based on case studies that resembled real-life conditions in vocational schools. These activities required students to integrate knowledge about student characteristics, digital media selection, assessment development, and learning strategies appropriate to the vocational context. In other words, Smart Andragogical LMS–Padlet successfully created a learning environment that enabled the formation of a more complete relationship between TPACK components.

The implementation results also showed that the use of Padlet as a collaborative reflection medium significantly contributed to improving the quality of learning. During the implementation process, students actively uploaded case analysis results, commented on their peers' work, and reflected on the designed learning strategies. These activities created more intense academic interactions than conventional discussion forums on an LMS. These findings align with research.(Garrison & Kanuka, 2004)which states that Padlet can improve collaboration, communication, and student engagement by providing a simple yet interactive visual discussion space. Through Padlet, students not only receive feedback from lecturers but also learn from the experiences of their peers, making the learning process more meaningful.

The collaborative learning applied in this research also supports the Community of Inquiry (CoI) theory developed byHrastinski, (2019); and Irawan et al., (2024)Within the CoI

framework, the quality of online learning is determined by three main components: teaching presence, social presence, and cognitive presence. The Smart Andragogical LMS—Padlet—is able to integrate these three components simultaneously. Teaching presence is realized through the systematic arrangement of learning activities and the provision of adaptive feedback by lecturers. Social presence emerges through discussion and reflection activities on Padlet, while cognitive presence develops when students analyze case studies, design learning solutions, and critically evaluate discussion results. The combination of these three components creates a more in-depth learning experience that impacts the improvement of prospective teachers' professional competence.

This concept is in line with the thinkingTondeur et al., (2020) AndArifin, (2020) which explains that Learning Analytics is a data-driven approach to understanding and optimizing the learning process. Data collected during the learning process is not simply an archive of student activity but can be processed into information that supports more accurate learning decision-making. In this study, the Behavioral Learning Analytics dashboard enabled lecturers to identify students with low participation rates, provide personalized feedback, and evaluate the effectiveness of learning strategies based on empirical evidence recorded by the system.

Thus, the results of this study indicate that the improvement in students' TPACK competencies is not solely due to the use of technology, but rather the result of a harmonious integration of andragogy principles, Padlet-based collaborative learning, and Behavioral Learning Analytics. These three components complement each other in creating an adaptive, reflective, collaborative, and data-driven learning environment. These findings strengthen the argument that LMS development for teacher professional education should not only focus on providing digital materials, but also need to be designed as a learning ecosystem capable of supporting the adult learning process as a whole.

**Behavioral Learning Analytics**

In addition to improving TPACK competencies, the implementation results show that the Smart Andragogical LMS–Padlet based on Behavioral Learning Analytics is able to increase student engagement during the learning process. Based on the implementation results, the level of student engagement reached an average of 93.86% with a very high category. The high level of engagement is reflected in the frequency of LMS access, active participation in Padlet discussions, timely submission of assignments, pedagogical reflection activities, and the intensity of interactions between students. These findings indicate that the developed system is not only successful in improving learning outcomes, but is also able to build sustainable student engagement throughout the learning process.

The increase in student engagement in this study is also closely related to the use of Behavioral Learning Analytics. All student activity on the LMS and Padlet is automatically recorded and analyzed to determine various indicators of learning engagement. This data includes login frequency, system access duration, number of interactions in discussion forums, assignment completion, and learning outcomes. The resulting information is then displayed in a visual dashboard so lecturers can track student progress in real time.

This approach is in line with the opinionIrawan et al., (2025); and Valtonen et al., (2020) which states that Learning Analytics enables educational institutions to transform learning activity data into information that can be used to improve the quality of learning. Data that was previously merely administrative records becomes the basis for academic decision-making. In this study, lecturers can quickly identify students who show decreased

participation, late completion of assignments, or low levels of reflection, allowing interventions to be implemented before students experience more serious learning difficulties.

The results of this study also support the findingsEutsler, (2022) AndBaran, (2019)which explains that Learning Analytics has four main functions: monitoring, analysis, prediction, and intervention. These four functions are implemented concretely in the Smart Andragogical LMS–Padlet. The system not only monitors student activity but also analyzes learning patterns, predicts the likelihood of success through chance of success indicators, and provides information that helps lecturers provide timely learning interventions. Thus, the Behavioral Learning Analytics dashboard functions not merely as a reporting tool but also as a supporting instrument in the adaptive learning process.

Furthermore, the results of this study are also in line with researchJin & Harp, (2020) which states that the integration of Learning Analytics into online learning can improve the quality of feedback, accelerate the process of identifying students in need of assistance, and increase the effectiveness of learning decision-making. In this study, lecturers no longer rely on end-of-semester evaluation results to track student progress. Instead, information about the learning process can be monitored continously through a dashboard, allowing for faster corrective action.

This finding is in line with researchHan et al., (2021) which states that the success of online learning is greatly influenced by the quality of interactions between students. The higher the level of interaction, the greater the opportunity for meaningful learning. In the Smart Andragogical LMS–Padlet, these interactions occur not only synchronously through class discussions but also asynchronously through Padlet, giving students sufficient time to reflect before responding to their peers.

The research results also support the Social Constructivism theory put forward by(Voogt et al., 2013), which emphasizes that knowledge is constructed through social interaction. Padlet provides a space for students to share experiences, provide feedback, and refine learning designs based on group discussions. Thus, the learning process is no longer individualistic, but develops through ongoing academic collaboration.

The results of this study demonstrate that digital transformation in teacher professional education is not simply achieved through the digitization of learning materials. More importantly, technology is leveraged to foster interaction, provide rapid feedback, support pedagogical reflection, and provide information that helps lecturers make objective learning decisions.(Annisa et al., 2025). Therefore, the success of Smart Andragogical LMS–Padlet lies not only in the use of technology, but in its ability to integrate technology with pedagogical approaches and adult learning principles in an integrated manner.

**Smart Andragogical LMS–Padlet**

The results of this study indicate that the Smart Andragogical LMS–Padlet based on Behavioral Learning Analytics not only results in increased TPACK competency and student engagement, but also offers a more comprehensive digital learning model compared to the online learning approach currently used in the Teacher Professional Program (PPG). These findings indicate that the success of digital learning transformation is not only determined by the availability of a Learning Management System (LMS) platform, but is more determined by how the technology is designed based on learner characteristics, supported by appropriate pedagogical strategies, and utilizes learning data as a basis for academic decision-making. Thus, the product developed in this study has

strategic value in supporting the implementation of adaptive, personalized, and sustainable digital learning.

One of the important findings of this study is that the integration of andragogy, Padlet, and Behavioral Learning Analytics creates a learning environment that accommodates the characteristics of PPG students as adult learners. To date, most LMSs have only served as a medium for distributing materials, collecting assignments, and conducting learning evaluations. However, PPG students differ from regular students in that most already have teaching experience in schools. This professional experience is a valuable learning resource and needs to be accommodated in the learning process. Smart Andragogical LMS–Padlet provides a space for students to share these experiences through reflection activities, case discussions, and academic collaboration, making learning more contextual.(Fakhriyah, 2022).

This finding strengthens the theory(Knowles et al., 2015) which states that adult learning will be more effective if learners are actively involved in the learning process, given the opportunity to utilize previous experiences, and given the freedom to manage the learning process. All of these principles are realized in the design of Smart Andragogical LMS–Padlet through case-based learning, reflective discussions, collaborative learning, and the provision of adaptive feedback based on the results of Behavioral Learning Analytics. Therefore, the success of the developed system comes not only from the use of technology, but also from the suitability of the learning approach to the characteristics of the users.

From an educational technology perspective, this study also demonstrates that Behavioral Learning Analytics plays a crucial role in improving the quality of learning. During implementation, the dashboard provides real-time information on student learning patterns, enabling lecturers to intervene more quickly with students experiencing decreased participation or learning difficulties. This approach supports the concept of precision education, which is learning designed based on the characteristics and needs of each individual student. Compared to conventional evaluation systems that rely solely on final exam results, a learning analytics-based approach provides far more comprehensive information because it considers the entire student learning process.

## Conclusion

The results of the study indicate that the Smart Andragogical LMS–Padlet based on Behavioral Learning Analytics successfully meets the needs of PPG students as adult learners through a collaborative, reflective, adaptive, and data-driven learning environment. The developed product integrates a Learning Management System (LMS), a Padlet-based reflection space, a Behavioral Learning Analytics dashboard, TPACK-based learning tools, and evaluation instruments. Expert validation results show a very good level of validity in the aspects of learning design, material suitability, technology integration, ease of use, and the quality of the analytical dashboard. Product implementation increased students' Technological Pedagogical Content Knowledge (TPACK) competency from 61.83 in the pretest to 86.47 in the posttest with an N-Gain of 0.65 (moderate category). The level of student engagement reached 93.86% (very high category). In addition to being able to record learning activities and visualize competency development in real time, the dashboard supports lecturers in making data-based learning decisions. These findings confirm that the Smart Andragogical LMS–Padlet functions as a digital learning medium

as well as an effective learning decision support system to improve the professional competency of prospective PPG Automotive Engineering teachers.

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