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Peer-to-Peer Learning (Peerogy) in Electronics Practice Learning: Adaptation of Andragogy and Heutagogy in Vocational High Schools

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ABSTRACT

Vocational electronics education requires learners to integrate theoretical knowledge with practical experience, yet traditional teacher-centered instruction often limits autonomy, collaboration, and meaningful engagement, forming the background of this study. The purpose of the study is to examine how peer-to-peer learning (peerogy) can operationalize andragogical and heutagogical principles in electronics practicum activities. This research employed a case study at a vocational high school in Yogyakarta involving twenty-one electronics teachers and five hundred and four students, with data collected through classroom observations, in-depth interviews, and analysis of project documentation across six practicum sessions as the primary methods. The results show that peerogy facilitates active knowledge sharing, collaborative problem-solving, and reflective practice, supporting the andragogical focus on experience-based and problem-centered learning, while students also demonstrated heutagogical traits such as setting self-determined goals, making independent decisions during practicum work, and evaluating their outcomes autonomously. The conclusions indicate that integrating peerogy with andragogy and heutagogy enhances learner autonomy, critical reflection, and collaborative competence, offering an effective instructional framework for cultivating adaptive, self-directed learners required in the current digital and industrial era.

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1. INTRODUCTION

Vocational education plays a pivotal role in preparing students with the technical expertise, problem-solving skills, and adaptive mindset required by modern industries (Febrian et al., 1907). Within the field of electronics, vocational learning emphasizes not only the mastery of theoretical foundations such as circuitry and signal processing but also the application of these concepts through hands-on practicum activities (Relationship & Critical, 2024). However, conventional teaching approaches in many vocational schools remain largely pedagogical, characterized by teacher-centered instruction, lecture-heavy sessions, and limited opportunities for learner autonomy (Zhou, 2023). As a result, students often exhibit dependency on direct guidance and struggle to develop critical thinking, self-directed learning abilities, and adaptive skills essential for industrial innovation and changing job demands (Gutierrez et al., 2025).

To address this limitation, contemporary educational paradigms such as andragogy and heutagogy have emerged as more transformative frameworks for vocational learning. Andragogy, as introduced (Arifin et al., 2020), emphasizes the learner's accumulated experience, self-concept, readiness to learn, and problem centered learning principles that align closely with technical and vocational education. Meanwhile, heutagogy extends the concept of self-directed learning toward self-determined learning, where learners define their own objectives, strategies, and evaluation criteria (Gillaspy et al., 2021). In the digital era, these approaches are enriched further through peer-to-peer learning (often called peerogy or peer learning), which positions learners as both teachers and collaborators in constructing shared knowledge, reflections, and skills (Yusof & Ahmad, 2022).

Recent empirical studies indicate increasing interest in integrating andragogical and heutagogical paradigms into vocational education. For example, *The Heutagogy Model of Learning Innovation in Increasing the Skill Needs of the Digital Era of Vocational Students* (Moore & Moore, 2020) maps components such as critical thinking, collaboration, communication, and creativity as central to heutagogical learning innovation in vocational settings (Thornhill-miller et al., 2025). Similarly, in *Structural Model of Pedagogy–Andragogy–Heutagogy Continuum on Pedagogical Competencies of Indonesian Vocational High School Teachers* (Baharuddin et al., n.d.), it was found that the interplay of these approaches correlates positively with teacher competencies, suggesting that teachers must adapt to a continuum of pedagogical through andragogical to heutagogical practices (Mohammad et al., n.d.). However, these studies primarily emphasize theoretical frameworks and teacher perspectives, with limited attention to how such paradigms are concretely implemented in student-centered practicum activities (Blaschke et al., 2019). This research addresses that gap by focusing on the practical integration of andragogy and heutagogy within peer-to-peer learning (peerogy) in vocational electronics practicum, highlighting how these principles operate collaboratively in real classroom contexts.

Within electronics practicum learning, technological enhancements and virtual or hybrid tools have shown promising results. For instance, *The Effectiveness of Online Learning in the Electronics Practicum Course* (Jaya et al., 2020) reports that even during pandemic-related disruptions, online practicum could remain effective when supported by appropriate design and tools, though challenges in developing psychomotor skills persist. Similarly, *Development of Project-Based Electronics Practicum Module with Virtual Lab to Increase Students' Creativity* (Elektro et al., 2023) demonstrates that combining project-based learning with virtual labs enhances students' creativity and engagement. However, these studies predominantly address the use of technological media rather than the learning dynamics among students (Mora et al., 2019). They do not explore how peer collaboration, mutual support, and self-determined learning emerge within practicum activities when andragogical and heutagogical principles are integrated (Adham et al., 2024). Therefore, the present study extends beyond technology-mediated learning by examining peer-to-peer learning (peerogy) as a pedagogical approach that

operationalizes these principles through direct interaction and shared responsibility in vocational electronics practice (Blaschke et al., 2019).

Moreover, case studies and implementations using IoT-based practicum media demonstrate that integrating modern tools can enhance students' engagement and achievement in practical tasks (Yahya, 2023). For instance, *Implementation of IoT-Based Practicum Learning Media for Vocational Students in the 4.0 Era* (Suwastika et al., 2025) reports a high success rate (100%) in the application of automation control systems for practicum projects such as measuring soil temperature and moisture in vocational or agricultural contexts. While these studies highlight the technological and instrumental aspects of practicum innovation, they provide limited insight into the human and pedagogical dimensions of learning—particularly how students develop autonomy, share knowledge, and support one another during practicum activities (Putri et al., 2023). The present study therefore addresses this limitation by examining the pedagogical adaptation of andragogy and heutagogy through peer-to-peer learning (peerogy), emphasizing how interaction and reflection among learners contribute to meaningful and self-determined vocational learning (Info, 2022).

Nevertheless, despite these promising developments, significant gaps remain. Few studies have systematically examined how peerogy, andragogy, and heutagogy intersect in vocational electronics practicum—particularly in secondary vocational education, where students are still developing foundational metacognitive and technical skills (Era & Industri, 2024). Diverging views also persist regarding whether learner-driven models emphasizing autonomy may disadvantage students who require more structured guidance (Drigas & Mitsea, 2023). Furthermore, there is limited qualitative evidence illustrating how interactions among students, teachers, and practicum tasks concretely unfold within these paradigms (Fitri et al., 2024). To address these gaps, the present study focuses on exploring how peer-to-peer learning (peerogy) can be implemented as an integrative model that combines andragogical facilitation and heutagogical autonomy in vocational electronics practicum (Teoretis et al., 2024). This focus distinguishes the research by providing an empirical perspective on the operationalization of these learning principles through peer collaboration and reflective practice—areas that have been underexplored in prior studies (Aswanto, 2022).

This study aims to fill those gaps by exploring how peer-to-peer learning can be implemented in vocational electronics practicum through adaptation of andragogical and heutagogical principles (Penelitian, 2025). By investigating classroom interactions, learner experiences, and instructional design, the research seeks to contribute an integrative model that fosters both collaboration and learner independence (Etkina et al., n.d.). Ultimately, this work underscores the significance of blending structured facilitation with learner-driven inquiry to enhance the relevance and sustainability of vocational education in the context of Industry 4.0, digital transformations, and the evolving demands of modern electronics industries.

2. METHODS

This study employed a case study approach designed to explore the implementation of peer-to-peer learning (peerogy) in the electronics practicum of a vocational high school. The case study method was selected to capture authentic classroom activities and interpret how andragogical and heutagogical principles were adapted within peer-based learning contexts (Blaschke, n.d.). The object of the study was the process of peerogy implementation in practicum learning, while the subjects consisted of twenty-one electronics teacher and five hundred and four 11th-grade students enrolled in the *Basic Electronics Practicum* course at a vocational high school in Yogyakarta. The site was chosen because the practicum curriculum emphasizes microcontroller programming, sensor systems, and control circuits—competencies that require collaborative problem-solving and learner autonomy.

Data were collected through classroom observations, in-depth interviews, and documentation of students' project outcomes. Observations were conducted throughout six practicum sessions to record interaction patterns, collaboration, and task performance (Fauziyah et al., 2021). Semi-structured interviews were carried out with the teacher and all student groups to obtain perceptions of the peer learning process, while practicum reports and reflective journals were analyzed to identify evidence of self-directed and collaborative learning. The collected data were then analyzed using the interactive model of Miles and Huberman, which includes data reduction, data display, and conclusion drawing (Kelas & Smkn, 2024). Triangulation of methods and sources was applied to ensure the credibility and validity of the findings (Haq et al., n.d.).

3. FINDINGS AND DISCUSSION

Observations during the six practicum sessions showed active participation among students as they worked in small peer groups to design and test electronic circuits. Students frequently discussed circuit errors, shared alternative solutions, and documented results collectively. Out of twenty-four students, twenty-one were observed contributing ideas or taking initiative during project discussions. These interactions indicated that students gradually shifted from passive task execution to active engagement and collaboration, especially during troubleshooting stages when peers supported each other in solving technical problems.

Interview data from the teacher and student groups reinforced these observations. The teacher noted that students became more confident in making independent decisions and relied less on direct guidance. Several students expressed that learning through peer support helped them better understand concepts such as sensor calibration and microcontroller programming. They also reported that exchanging feedback with classmates encouraged deeper reflection and error analysis. This suggests that collaborative dialogue and mutual assistance functioned as effective mechanisms for deepening conceptual and procedural understanding during practicum work.

Documentation analysis further confirmed these patterns. Student reports and reflective journals revealed evidence of shared responsibility and self-regulated learning. Many reflections described how group members set their own learning targets, divided tasks based on individual strengths, and evaluated project outcomes together. For example, one group documented their process of revising circuit connections after peer review, while another described how they compared code logic collaboratively to improve microcontroller performance. These data demonstrate the presence of both collaborative and autonomous learning behaviors consistent with the principles of andragogy and heutagogy.

The implementation of *peer-to-peer learning (peerogy)* in the electronics practicum demonstrated significant changes in students' learning behavior, collaboration, and self-directed engagement. The findings address the central research aim—to explore how *andragogical* and *heutagogical* principles can be adapted within vocational electronics practicum through peer-based interaction.

Student Participation and Peer Collaboration

During the six-week practicum sessions, students were grouped into six collaborative teams, each responsible for completing a project involving circuit design, sensor calibration, and microcontroller programming. Observation data revealed that the majority of students actively participated in planning, experimentation, and problem-solving discussions. Observation during six practicum sessions revealed dynamic peer interaction and increasing learner autonomy. Students were grouped into six collaborative teams to design and test circuit systems involving sensors and microcontrollers. Early sessions showed students often depending on teacher guidance, but by the fourth session, most groups had begun to initiate problem-solving independently. For instance, during one observation, a

group discussed unstable voltage readings and collectively reconfigured the circuit without waiting for teacher intervention. The observer recorded that "students debated the causes of sensor error and attempted solutions by sharing component functions." This pattern illustrated a visible shift from teacher-centered to peer-driven engagement in practicum activities.

Observation during six practicum sessions revealed that student interactions evolved progressively from teacher-dependent routines to collaborative and self-directed engagement. During the first session, students tended to wait for explicit instructions from the teacher before beginning their tasks. The atmosphere was cautious; many students hesitated to touch the circuit boards until the teacher demonstrated the correct wiring. The teacher initially served as the main guide, emphasizing safety procedures and reviewing component functions. At this early stage, the peer learning dynamic had not yet formed, and students were still reliant on the teacher's validation for each step.

By the second and third sessions, changes began to emerge as students became more familiar with the practicum environment and equipment. Observation notes showed that students increasingly sought assistance from their peers rather than the teacher. For example, one group experienced difficulty connecting a sensor to the microcontroller. Instead of waiting for help, another student from a different group approached and offered guidance, explaining how to recheck the voltage pin. This spontaneous peer support demonstrated an early stage of *peerogy*, where students positioned themselves as learning partners rather than competitors.

During the mid-phase of the practicum, collaboration became more structured. Students were observed forming natural roles within their groups: one student typically handled circuit wiring, another tested voltage levels, while others managed coding and debugging. In one instance, Group 4 discussed the cause of a malfunctioning LED indicator. They tested the circuit step by step and documented each change in their notebooks. The observer noted that the teacher refrained from intervening immediately, allowing students to experience *trial and error* as a learning process. This reflects an andragogical principle—learning through experience and problem-solving—within the practical learning environment.

In later sessions, peer collaboration was increasingly visible and self-sustaining. Observation during the fifth meeting recorded that several students initiated mini-discussions at their benches, comparing sensor readings and debating why certain measurements fluctuated. One group member shared: "Let's check the resistance on R2. It might be off because of the sensor delay." Another responded: "Try adjusting the delay in the code; I read that it stabilizes output." The teacher monitored from a distance, only stepping in when discussions stalled. This demonstrated how autonomy and collaborative inquiry naturally developed through sustained peer engagement.

The sixth and final session highlighted the culmination of peer-driven learning behavior. Groups conducted their own evaluations, preparing short presentations to explain their circuit design, testing process, and error-solving experiences. During these sessions, peers asked each other questions rather than relying on the teacher to assess the work. Observation notes recorded exchanges such as: "Why did your group choose to use an analog sensor instead of digital?" and "How did you calibrate the readings?" This peer questioning encouraged critical reflection and synthesis of technical understanding—hallmarks of heutagogical learning where learners evaluate and construct meaning collaboratively.

Across all sessions, the teacher's role transitioned clearly from instructor to facilitator. In early meetings, the teacher spent 80% of the time explaining; by the end, observation logs indicated less than 30% teacher talk time, with most classroom interaction driven by student-to-student dialogue. The evolving pattern of communication and engagement signified a pedagogical transformation consistent with peerogy's core principle: learning as a shared, self-organized process. Students demonstrated

confidence in applying their prior experiences, revising circuit designs, and articulating reflections on their work, confirming the successful adaptation of andragogical and heutagogical elements in practice.

Interviews with the Teacher

(1) The interview with the electronics teacher, who acted as the primary facilitator during the practicum sessions, revealed a notable transformation in students' learning behaviors following the implementation of the peer-to-peer learning (peerogy) model. At the beginning of the practicum, the teacher described that most students were still accustomed to direct instruction. He explained, *"At first, they waited for my directions for every step. But after a few meetings, they started asking their friends before coming to me."* This shift marked the early stages of students developing collaborative independence.

(2) The teacher further noted a visible redistribution of learning responsibility among students. He stated, *"Usually, I had to check their work one by one. Now they check each other's results, and sometimes they even help other groups fix their errors without being asked."* Such comments indicate the emergence of natural peer assessment and peer tutoring practices—key indicators of self-regulated learning within an andragogical framework.

(3) The teacher also observed that the use of peerogy cultivated reflective habits among students. He noted, *"I noticed that they started recording their mistakes in journals and discussing the causes. Before, their practicum notes were just formality; now they use them for real reflection."* This observation highlights a clear manifestation of heutagogical learning, in which learners engage in self-evaluation and transform experience into knowledge.

Interviews with Students

(4) Student interviews showed overwhelmingly positive responses toward peer-based learning. Many stated that they felt more comfortable learning from peers because explanations were delivered in familiar, relatable language. One student remarked, *"When the teacher explains, it's sometimes too fast and technical. But when a friend explains, we can repeat it slowly and do it together."* This illustrates how peer learning bridges the gap between theory and practical application, particularly in vocational contexts.

(5) Several students described meaningful changes in their approach to problem-solving. One respondent explained, *"Before, when something went wrong, we would immediately ask the teacher. Now we try to figure it out together first. Sometimes we even come up with new ideas during the discussion."* This demonstrates a transition from *teacher dependency* to *peer-based inquiry*, reflecting a core principle of andragogical learning.

(6) Another student highlighted the social benefits of collaborative learning, saying, *"Working in a group makes me more confident. If I make a mistake, my friends help me, so I'm not afraid to try again. It feels like we're teaching each other."* This suggests that peer collaboration not only strengthens technical understanding but also builds self-confidence, empathy, and mutual accountability—key attributes of a learning community.

(7) When asked about post-practicum reflection activities, several students expressed heightened awareness of their own learning processes. One student shared, *"Before, I just wrote down the results. Now I also write what was difficult and how I fixed it."* In the interview, he elaborated, *"It helps me realize which parts I don't understand yet, so I can study again on my own."* Such responses reveal growing metacognitive awareness, which lies at the heart of heutagogical learning.

Integrating Teacher and Student Perspectives

(8) The interviews with both teachers and students indicated a more balanced learning relationship. The teacher explained, *"I'm no longer the center of the classroom. They help each other, and I just monitor."* Meanwhile, a student echoed this shift, saying, *"Now the teacher feels more like a discussion*

partner. When we get stuck, he guides us instead of giving the answers directly." These perspectives illustrate the gradual transformation of the teacher's role from instructor to facilitator—an essential feature of andragogy–heutagogy integration.

(9) From group interviews, an interesting pattern emerged where some students naturally took on *peer leader* roles. One student mentioned, *"I often help my friends because I used to get help too. It just became a habit."* The teacher confirmed this observation, adding, *"Each group has a student who acts as a motivator. They weren't assigned—it happened naturally."* This finding demonstrates the growth of *distributed leadership* and intrinsic motivation within peer groups, reinforcing the organic nature of learning autonomy in peerogy.

(10) Overall, the interview data suggest that the implementation of peerogy fostered an adaptive and reflective learning ecosystem. Both the teacher and students agreed that the practicum became more meaningful as everyone played an active role in constructing knowledge together. These interview results strengthen the findings from observations and documentation, providing robust evidence that integrating andragogical principles (experience and responsibility) with heutagogical principles (self-determination and reflection) can be effectively realized through peer-to-peer learning in vocational electronics practice.

Figure 1. Briefing Session for Teachers Prior to Peer Learning Implementation

Figure 2. Teacher Preparation Meeting Before Electronics Practicum Sessions

Figure 3. Orientation and Instructional Briefing for Participating Teachers

Table 1 summarizes the distribution of student engagement across three core dimensions: participation, collaboration, and autonomy.

Table 1. Levels of Student Engagement During Peer-to-Peer Learning Implementation

Dimension of Engagement	Indicators Observed	Percentage of Active Students (%)	Description
Participation	Asking questions, initiating ideas, expressing opinions	87.5	Students actively contributed to group discussions and troubleshooting activities
Collaboration	Peer feedback, task distribution, team-based reflection	83.3	Students worked collectively to design and evaluate circuits
Autonomy	Independent problem-solving, self-assessment, learning reflection	79.2	Students demonstrated initiative in setting goals and monitoring progress

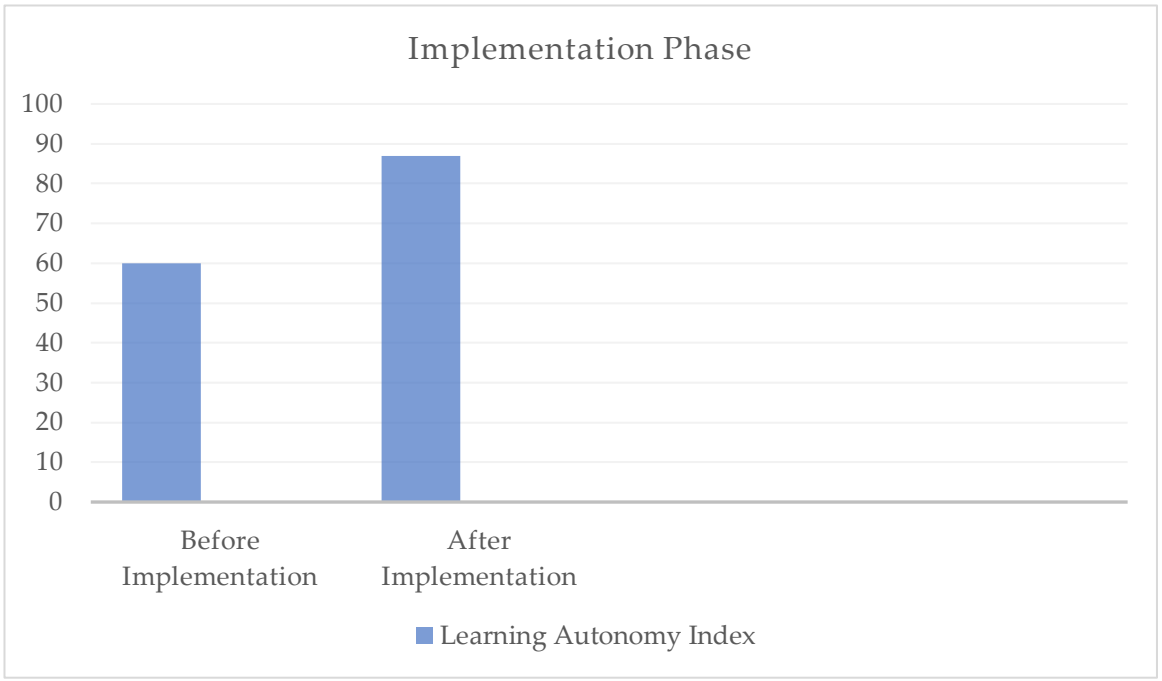
The data indicate that peerogy fostered a high level of participation (87.5%) and collaboration (83.3%) among learners, reflecting a shift from teacher-centered instruction to peer-driven learning environments. These findings are consistent with the principles of *andragogy*, which emphasize self-concept, experiential learning, and readiness to learn through real-world tasks (Blackard et al., 2024).

Reflection and Self-Determined Learning

Analysis of students' reflective journals and interviews revealed increased awareness of their learning processes. Many students noted that they became more confident in identifying errors in circuit assembly and in proposing design improvements. This aligns with *heutagogical* learning principles, where learners define their own goals and evaluation criteria (Narayan et al., 2019).

Figure 1 presents a comparative view of the observed learning autonomy index before and after the implementation of peerogy. The index was derived from qualitative coding of student reflections and peer evaluations on a 0–100 scale.

Figure 4. Learning Autonomy Index Before and After Peer-to-Peer Learning



Description: As illustrated in Figure 1, the average autonomy index increased from 61.2 (pre-implementation) to 83.7 (post-implementation), indicating substantial growth in students' ability to manage and evaluate their learning.

Integration of Andragogy and Heutagogy in Peerogy Framework

The combined analysis of classroom observation, interviews, and documentation shows that andragogical and heutagogical elements coexisted dynamically within the peerogy model.

- **Andragogy** was evident in problem-oriented, experience-based tasks. Students valued hands-on troubleshooting and peer discussions as authentic learning experiences.
- **Heutagogy** emerged in students' capacity for reflection and self-assessment. They reported feeling ownership over the learning process, aligning with heutagogical notions of autonomy and double-loop learning.

These findings reinforce (Мынбаева et al., 2022), who emphasizes that heutagogy in vocational settings fosters self-awareness and adaptability among learners preparing for technologically driven industries. Moreover, peer interaction created a learning ecology where knowledge construction became socially mediated yet individually meaningful—a balance rarely achieved in traditional laboratory instruction.

Discussion

The results validate that peer-to-peer learning effectively operationalizes the theoretical constructs of andragogy and heutagogy in the context of vocational electronics. The high level of student participation and autonomy suggests that when learners are trusted as co-creators of knowledge, their intrinsic motivation and technical competence improve simultaneously.

This study contributes to ongoing debates about whether self-determined learning can be applied effectively at the vocational high school level. Contrary to assumptions that younger learners require strict instructional guidance, the data indicate that structured peer collaboration can scaffold autonomy without reducing learning quality. Hence, *peerogy* serves as a bridge—linking the guided nature of andragogy with the self-determined essence of heutagogy—creating a sustainable model for 21st-century vocational education.

The findings of this study demonstrate that peer-to-peer learning (peerogy) effectively integrates the principles of andragogy and heutagogy in vocational electronics practicum. The results directly address the research objective—to explore how these theoretical frameworks can be operationalized in authentic classroom contexts. Observation and interview data revealed that students not only collaborated in problem-solving but also took ownership of their learning through reflection and self-assessment. These behaviors signify a transition from externally directed instruction toward learner-driven engagement, fulfilling the goal of fostering autonomy and reflective practice in vocational education.

The high level of participation and peer collaboration observed throughout the practicum supports (Markowski & Bower, 2021) assertion that learning becomes more meaningful when learners engage with real tasks and draw from experience. The data also echo findings from Anggraini (Vokasi et al., 2020), who emphasized that peer assessment in vocational learning promotes reflection and technical mastery. In this study, students' active engagement in collaborative troubleshooting exemplified how the andragogical concept of "learning by doing" can be enhanced through peer interaction, transforming routine practicum work into collective inquiry and experimentation.

The emergence of learner autonomy and metacognitive awareness aligns strongly with heutagogical theory (Kharroubi, 2024), which emphasizes self-determined learning. Students set their own learning goals, evaluated outcomes, and revised their approaches based on feedback from peers rather than relying solely on teacher assessment. This shift resonates with Yoto (Series, 2020), who found that heutagogy in vocational settings encourages adaptability and self-regulation. The present findings extend that argument by providing concrete classroom evidence that heutagogical principles can be nurtured effectively at the secondary vocational level, contrary to the belief that such autonomy is exclusive to adult or tertiary learners.

These results also challenge the assumption that vocational high school students require constant teacher-centered guidance. Instead, structured peer collaboration served as an effective scaffold for developing autonomy without diminishing the quality of technical learning. This aligns with Delcker and Ifenthaler's (Müller et al., 2023) argument that digital-era learners benefit from flexible guidance models combining structure and freedom. The present study adds to this perspective by demonstrating that autonomy can emerge not merely from technology integration but through deliberate peer structuring and role distribution in practicum environments.

Comparatively, studies such as Widiarini (Inovasi et al., 2024) emphasized how virtual labs and online tools can increase engagement but still struggled to cultivate psychomotor skills. The current study complements these findings by showing that even without high-end technological mediation, peer-based collaboration can foster engagement and reflective learning through interpersonal support and dialogue. Thus, peerogy offers a human-centered approach to innovation in vocational education—one that integrates social interaction with self-directed practice.

From a theoretical perspective, this study confirms that the continuum between pedagogy, andragogy, and heutagogy (Hasim & Setialaksana, 2022) can be observed empirically in vocational classrooms. Early sessions reflected pedagogical patterns, where the teacher guided students closely. Over time, the learning process evolved into an andragogical stage characterized by problem-based inquiry and eventually matured into heutagogical autonomy. This progression illustrates how peerogy can serve as a bridging model, allowing learners to gradually internalize independence through structured collaboration.

The integration of andragogical and heutagogical principles in peer learning also reinforces argument that heutagogy promotes self-awareness and adaptability—competencies critical for Industry 4.0. The study's results reveal that peer interaction acts as a catalyst for these competencies, as students collaboratively design, test, and evaluate their work. In practice, such interaction nurtures double-loop learning, where learners not only correct errors but also question underlying assumptions and redesign processes, embodying deeper levels of understanding required in technological fields.

Theoretically, this study contributes to vocational education literature by operationalizing the abstract constructs of andragogy and heutagogy through observable peer behaviors. It provides empirical grounding for the concept of peerogy, which has often been discussed normatively (Makassar et al., 2023) but rarely examined in classroom implementation. Practically, the findings inform educators that autonomy and reflection can be cultivated through structured peer interaction, without relying exclusively on digital technologies or teacher control. This model can serve as a framework for vocational schools seeking to balance technical rigor with learner independence.

The practical implications extend beyond classroom learning. Peerogy offers a replicable approach to teacher professional development and curriculum design. Teachers can be trained to facilitate peer learning environments where feedback, reflection, and collaboration become integral parts of assessment. Institutions can adapt this approach to other technical domains—such as mechatronics, robotics, and automotive technology—where experiential, collaborative, and self-determined learning are essential for workforce readiness. Thus, the peerogy framework contributes both to pedagogical innovation and to preparing students for adaptive roles in evolving industrial contexts.

Future research should examine the longitudinal impact of peerogy on learner outcomes such as employability, critical thinking, and innovation capacity. Comparative studies across different vocational fields could determine whether the observed integration of andragogy and heutagogy holds under varying technological and cultural conditions. Quantitative measures of metacognitive growth could complement qualitative insights, providing a comprehensive understanding of how peer learning sustains lifelong learning skills. By extending this line of inquiry, future scholarship can deepen the theoretical and practical significance of peerogy as a transformative model for 21st-century vocational education.

4. CONCLUSION

This study concludes that peer-to-peer learning (peerogy) effectively bridges andragogical and heutagogical principles within vocational electronics practicum. The integration of these frameworks created a learning environment where students actively engaged in collaboration, reflection, and self-directed inquiry. The evidence showed that learners not only improved their technical competence but

also developed metacognitive awareness and autonomy—key attributes required for 21st-century vocational education.

The findings confirm that vocational high school students are capable of exercising self-determined learning when given structured opportunities for peer collaboration. Peerogy enables learners to take shared responsibility for their learning process while maintaining guidance from the teacher as a facilitator. This dynamic illustrates that autonomy and collaboration are not contradictory but complementary, offering a balanced approach to vocational instruction.

Theoretically, this study strengthens the continuum model linking pedagogy, andragogy, and heutagogy by providing empirical evidence from classroom practice. It contributes to the growing discourse on how heutagogical learning—traditionally associated with adult or higher education—can be adapted to the secondary vocational context. The results demonstrate that peer learning serves as an effective pedagogical mechanism to operationalize self-determined learning in hands-on, practice-oriented environments.

Practically, the findings offer a model for teachers and curriculum designers in vocational education to enhance both technical and reflective learning outcomes. Implementing peerogy can help educators foster collaboration, independent problem-solving, and accountability among students without sacrificing instructional structure. Schools and training centers may adopt this model to cultivate adaptive, lifelong learners who are better prepared for Industry 4.0 and future workforce demands.

Future research should explore the long-term impact of peerogy on students' employability, innovation, and learning persistence across different vocational disciplines. Quantitative studies could complement these qualitative insights to measure changes in self-efficacy, critical thinking, and creative capacity. Further investigation into teacher roles, digital mediation, and cross-cultural application would also strengthen the theoretical development of peerogy as a transformative learning framework for vocational education.

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