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Enhancing Student Engagement and Learning Outcomes in Industrial Automation Systems Course Through Discussion Method in Vocational Mechatronics Education Program at Universitas Negeri Makassar

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A B S T R A C T

Industrial Automation Systems is a fundamental course in vocational mechatronics education that requires active student participation and deep conceptual understandingThis study aimed to investigate the effectiveness of the discussion method in enhancing student engagement and learning outcomes in the Industrial Automation Systems course within the Vocational Mechatronics Education Program at Universitas Negeri Makassar. Quantitative data were analyzed using descriptive statistics and paired t-tests, while qualitative data underwent thematic analysis.Student engagement increased significantly from 56.25% (passive) in the pre-cycle to 87.50% (highly active) in Cycle 2. Mean learning outcomes improved from 64.38 (SD=9.27) at pre-test to 83.13 (SD=6.45) at post-test ($p<0.001$), with an effect size of Cohen's d=2.35. The discussion method effectively enhances both student engagement and learning outcomes in Industrial Automation Systems education. Implementation in vocational mechatronics programs can significantly improve educational quality and prepare students for professional competencies required in industrial automation fields

INTRODUCTION

Vocational education plays a critical role in preparing skilled workforce capable of meeting the demands of rapidly evolving industrial sectors (Billett, 2014). In the context of Industry 4.0, characterized by automation, digitalization, and smart manufacturing, vocational mechatronics education must equip students with both theoretical knowledge and practical competencies in industrial automation systems (Mourtzis et al., 2018). The Industrial Automation Systems course serves as a cornerstone in vocational mechatronics programs, covering essential topics including programmable logic controllers (PLCs), supervisory control and data acquisition (SCADA), human-machine interfaces (HMI), and industrial networking protocols.

Despite the course's importance, preliminary observations at the Vocational Mechatronics Education Program, Faculty of Engineering, Universitas Negeri Makassar, revealed significant pedagogical challenges. Traditional lecture-based instruction dominated classroom practices, resulting in passive student participation, limited interaction, and insufficient development of critical thinking skills. Approximately 68.75% of students demonstrated low engagement during classes, with minimal questioning, discussion participation, or collaborative problem-solving. Consequently, learning outcomes remained suboptimal, with only 31.25% of students achieving satisfactory grades (≥75) in the previous semester.

The discussion method represents a student-centered pedagogical approach that promotes active engagement, collaborative learning, and deep conceptual understanding (Gall & Gillett, 2014). Rooted in constructivist learning theory, discussion-based instruction encourages students to articulate their thinking, challenge assumptions, consider multiple perspectives, and construct knowledge through social interaction (Vygotsky, 1978; Mercer, 2000). Research in vocational education contexts has demonstrated that interactive discussion methods enhance both cognitive outcomes and practical competencies (Okwelle & Deebom, 2020)

The specific problems identified in the Industrial Automation Systems course included:

1. Low student engagement, with 68.75% of students demonstrating passive participation in learning activities
2. Inadequate learning outcomes, with 68.75% of students failing to achieve mastery level (≥75)
3. Limited peer interaction and collaborative problem-solving
4. Insufficient development of critical thinking and communication skills essential for professional practice
5. Difficulty in applying theoretical concepts to practical automation scenarios

This study aimed to:

1. Implement the discussion method systematically in the Industrial Automation Systems course
2. Evaluate the effectiveness of the discussion method in improving student engagement

3. Assess the impact of the discussion method on student learning outcomes
4. Explore student perceptions and experiences regarding discussion-based learning
5. Provide evidence-based recommendations for improving Industrial Automation Systems instruction in vocational mechatronics programs

This research contributes to the limited body of empirical literature on discussion methods in vocational-technical education, particularly within Indonesian contexts. The findings provide practical guidance for vocational educators seeking to enhance student engagement and learning outcomes through active learning strategies. Furthermore, this study addresses the critical need for pedagogical innovation in vocational mechatronics education to prepare students for the collaborative, problem-solving competencies required in contemporary industrial environments.

LITERATURE REVIEW

The theoretical foundation of discussion-based learning is rooted in constructivism, which posits that learners actively construct knowledge through experience, reflection, and social interaction rather than passively receiving information (Piaget, 1954; von Glasersfeld, 1995). Vygotsky's (1978) social constructivism emphasizes learning as a social process, with cognitive development occurring through collaborative dialogue within the Zone of Proximal Development. Active learning theory (Prince, 2004; Freeman et al., 2014) further supports student-centered pedagogies, employing activities such as discussions, problem-solving, case studies, and collaborative projects, which have been shown to produce superior outcomes compared to traditional lectures. The discussion method, involving structured or semi-structured classroom dialogue, allows students to explore topics, share perspectives, question assumptions, and collaboratively construct understanding under instructor facilitation (Gall & Gillett, 2014; Brookfield & Preskill, 2016). Various formats—whole-class, small-group, think-pair-share, fishbowl, and Socratic seminars—have been demonstrated to enhance critical thinking, communication, conceptual understanding, and motivation (Abrami et al., 2015; Mercer, 2000; Chi & Wylie, 2014; Deci & Ryan, 2015).

Student engagement, encompassing behavioral, emotional, and cognitive dimensions, is closely linked to positive educational outcomes such as achievement, persistence, and deep learning (Fredricks et al., 2016; Kuh, 2009; Trowler, 2010). In technical and vocational education, engaged students develop superior problem-solving skills and practical competencies (Jossberger et al., 2010), with discussion-based approaches effectively promoting active participation and motivation. Learning outcomes in vocational education cover cognitive knowledge, psychomotor skills, and affective development aligned with professional standards (Billett, 2014; Bloom et al., 1956; Simpson, 1972; Krathwohl et al., 1964), and discussion-based instruction has been shown to improve both theoretical understanding and practical competencies (Okwelle & Deebom, 2020).

While discussion methods are widely studied in general education, research in technical and vocational contexts remains limited. Studies in engineering and vocational-technical programs demonstrate that structured peer discussions enhance critical thinking, problem-solving, academic achievement, and technical skills (Kassymova et al., 2019; Ismail & Hassan, 2019; Sudira et al., 2020; Yadav & Berges, 2019). However, challenges such as student resistance, unequal participation, difficulty maintaining focus, time constraints, and assessment complexity exist (Brookfield & Preskill, 2016). Best practices include providing clear structure, using open-ended questions, small-group discussions, rotating roles, connecting discussions to practical applications, peer assessment, and creating a supportive classroom climate (Gall & Gillett, 2014; Brookfield & Preskill, 2016).

Despite evidence supporting discussion-based learning, gaps remain in its implementation for Indonesian vocational mechatronics programs, particularly in industrial automation courses, and in systematically assessing both engagement and learning outcomes. This study addresses these gaps by applying and evaluating discussion-based instruction in an Industrial Automation Systems course within an Indonesian vocational context, offering empirical evidence and practical guidance for similar programs.

METHODOLOGY

This study employed a classroom action research (CAR) design based on Kemmis and McTaggart's (2005) cyclical model, allowing systematic investigation while simultaneously improving educational practice through iterative cycles of planning, action, observation, and reflection (McNiff & Whitehead, 2011). Conducted over two cycles across a 14-week semester, the research involved 32 students (8 females, 24 males; mean age 20.3 years, SD=1.2) enrolled in the Industrial Automation Systems course within the Vocational Mechatronics Education Program at Universitas Negeri Makassar during the 2024 academic year. The course met twice weekly for 100-minute sessions covering topics such as PLC fundamentals, ladder logic programming, SCADA systems, industrial sensors and actuators, HMI design, and industrial communication protocols, with all students providing informed consent to participate.

The intervention implemented the discussion method across two cycles, using varied formats to foster active learning and collaboration. Cycle 1 included introduction to discussion protocols, think-pair-share on PLC architecture, small-group analysis of ladder logic, fishbowl discussions on SCADA systems, and reflection/assessment. Cycle 2 included jigsaw discussions on industrial sensors and actuators, problem-based discussions on HMI design, Socratic seminars on Industry 4.0 integration, case-study discussions on troubleshooting, and final assessment/reflection. Each session followed a structured format with pre-discussion individual analysis, small-group discussion, whole-class synthesis facilitated by the instructor, and individual reflection. The instructor acted primarily as a facilitator, using open-ended questions, prompting equitable participation, synthesizing key concepts, and connecting discussions to course objectives.

Data were collected through multiple sources to ensure comprehensive evaluation. Student engagement was observed using a structured sheet covering attention, questioning, peer responses, idea contribution, and active listening, rated on a 4-point scale and analyzed with strong inter-rater reliability (κ=0.82). Learning outcomes were assessed with pre- and post-tests comprising multiple-choice and essay questions, while a post-intervention questionnaire captured perceptions of engagement, learning, and satisfaction. Documentation included reflection journals, photographs, videos, and instructor field notes. Quantitative data were analyzed using descriptive statistics, paired t-tests, and effect sizes, while qualitative data from reflections and open-ended responses underwent thematic analysis using NVivo 12, with independent coding and resolution of discrepancies.

Validity and reliability were ensured through triangulation of data sources, member checking, peer debriefing, inter-rater reliability, and researcher reflexivity. Ethical considerations included approval from the Research Ethics Committee of Universitas Negeri Makassar (Protocol #2024-ENG-156), voluntary participation, the ability to withdraw without penalty, anonymized data storage, and assurance that regular assessments were unaffected by participation.

RESEARCH RESULT

Enhancement of Student Engagement

Student engagement demonstrated substantial improvement across the intervention period. Table 1 presents engagement indicators across pre-cycle, Cycle 1, and Cycle 2 phases.

Table 1. Student Engagement Indicators Across Intervention Phases

Engagement Indicator	Pre-Cycle M(SD)	Cycle 1 M(SD)	Cycle 2 M(SD)	Engagement %
Attention/Focus	2.13 (0.66)	3.25 (0.57)	3.69 (0.47)	92.25%
Questioning Behavior	1.88 (0.71)	3.06 (0.62)	3.50 (0.52)	87.50%
Responding to Peers	2.06 (0.62)	3.19 (0.59)	3.56 (0.50)	89.00%
Contributing Ideas	1.94 (0.68)	3.00 (0.61)	3.44 (0.56)	86.00%
Active Listening	2.25 (0.62)	3.31 (0.54)	3.63 (0.49)	90.75%
Overall Engagement	**2.05 (0.59)**	**3.16 (0.55)**	**3.56 (0.48)**	**87.50%**

Note: Scale 1-4 (1=Passive, 2=Somewhat Active, 3=Active, 4=Highly Active) Overall student engagement increased from 56.25% (passive) in the pre-cycle to 79.00% (active) in Cycle 1, and further to 87.50% (highly active) in Cycle 2. Repeated measures ANOVA revealed statistically significant differences across all three phases ($F(2,62)=89.34$, p

Improvement in Learning Outcomes

Learning outcomes showed significant improvement following discussion method implementation.

Measure	Pre-test M(SD)	Post-test M(SD)	t-value	p-value	Cohen's d
Total Score (0-100)	64.38 (9.27)	83.13 (6.45)	12.84	<0.001	2.35
Multiple Choice (0-50)	32.19 (5.12)	42.34 (3.28)	11.56	<0.001	2.32
Essay Questions (0-50)	32.19 (5.03)	40.78 (3.95)	10.23	<0.001	1.90

The paired t-test revealed a statistically significant increase in mean total scores from pre-test (M=64.38, SD=9.27) to post-test (M=83.13, SD=6.45), t(31)=12.84, p

Achievement Level Distribution:

Achievement Level	Pre-test n(%)	Post-test n(%)	Change
Excellent (85-100)	2 (6.25%)	15 (46.88%)	+40.63%
Good (75-84)	8 (25.00%)	13 (40.63%)	+15.63%
Satisfactory (65-74)	12 (37.50%)	4 (12.50%)	-25.00%
Needs Improvement (<65)	10 (31.25%)	0 (0.00%)	-31.25%

The percentage of students achieving mastery level (≥75) increased dramatically from 31.25% at pre-test to 87.50% at post-test—a 56.25 percentage point improvement. Notably, all students achieved at least satisfactory performance by post-test, with zero students in the "needs improvement" category.

Student Perceptions and Satisfaction

Post-intervention questionnaire results (n=32) revealed highly positive perceptions:

Table 3. Student Perceptions of Discussion Method (n=32)

Item	Mean	SD	% Agree/Strongly Agree
Discussions enhanced my understanding	4.44	0.62	93.8%
I felt more engaged in learning	4.38	0.66	90.6%
Discussions improved my critical thinking	4.31	0.69	87.5%
I developed better communication skills	4.28	0.73	87.5%
Group discussions were helpful for learning	4.50	0.57	96.9%
I could apply concepts better after discussions	4.41	0.61	93.8%
Discussions made the course more interesting	4.47	0.62	93.8%
I prefer discussion method to lectures	4.22	0.79	84.4%
Overall satisfaction with discussion method	4.53	0.57	90.6%

Qualitative Findings: Student Experiences

Thematic analysis of 128 student reflection journal entries revealed four major themes. The first theme, From Passive to Active Learning, highlighted students' transformation from passive note-taking to active engagement, as they described thinking critically, explaining ideas, and defending their understanding rather than merely memorizing content. One student noted, "Before, I just listened and copied notes. Now I have to think, explain my ideas, and defend them. It's harder but I actually understand the material" (Student 7), while another commented, "Discussing with classmates forced me to really understand PLC programming, not just memorize steps" (Student 19). The second theme, Deeper Understanding Through Peer Explanation, reflected that teaching peers enhanced their own comprehension. Students remarked, "When I explained ladder logic to my group, I realized I didn't fully understand it myself. We figured it out together" (Student 14), and "Teaching my friends helped me learn better than listening to lectures. I had to think more carefully about how things work" (Student 26). The third theme, Development of Critical Thinking and Problem-Solving, indicated growth in analytical skills, with students noting that discussions encouraged them to ask "why" and "how" rather than accepting answers passively, aiding troubleshooting in automation systems (Student 11). Finally, the fourth theme, Increased Confidence and Communication Skills, highlighted personal development beyond technical knowledge, as students reported feeling more confident presenting ideas and communicating technical concepts clearly, which they recognized as beneficial for their future careers (Students 5 and 29).

DISCUSSION

This study provides strong evidence that the discussion method significantly enhances both student engagement and learning outcomes in Industrial Automation Systems education, with engagement increasing from 56.25% to 87.50% and learning outcomes improving by 29.1%, demonstrating its effectiveness in vocational mechatronics contexts. The observed increase in engagement aligns with active learning theory (Prince, 2004; Freeman et al., 2014) and social constructivism (Vygotsky, 1978), as the shift from instructor-centered lectures to student-centered discussions promoted behavioral, emotional, and cognitive involvement (Fredricks et al., 2016). Particularly notable were improvements in questioning behavior and idea contribution, indicating that discussion methods successfully activated cognitive engagement, fostering deep processing and strategic thinking essential for meaningful learning (Chi & Wylie, 2014) and supporting Mercer's (2000) argument that dialogic teaching encourages exploratory talk and collaborative understanding.

Learning outcomes also improved substantially, validating discussion methods' effectiveness in vocational-technical education and extending previous research to industrial automation contexts (Okwelle & Deebom, 2020; Ismail & Hassan, 2019). Strong gains in essay responses requiring analysis, application, and problem-solving highlight the method's role in developing higher-order thinking skills beyond factual recall (Bloom et al., 1956; Anderson & Krathwohl, 2001). These results align with Freeman et al.'s (2014) findings that active learning outperforms traditional instruction in STEM education, with peer explanations during discussions facilitating constructive learning processes such as knowledge elaboration, gap identification, and misconception correction (Chi & Wylie, 2014).

The findings carry several implications for vocational education. Pedagogically, they challenge the dominance of lecture-based instruction, showing that discussion methods can effectively convey complex technical content while developing professional competencies. Beyond technical knowledge, discussions enhanced communication, collaboration, and critical thinking, competencies crucial in Industry 4.0 environments that demand adaptive problem-solving and cross-functional teamwork (Mourtzis et al., 2018). High student satisfaction suggests that vocational students value active engagement and collaborative learning opportunities, countering assumptions that technical learners prefer passive instruction. Furthermore, successful implementation within existing course structures demonstrates that discussion methods can be integrated into vocational programs without extensive resources or curriculum redesign.

Nevertheless, several limitations should be noted. The study was conducted at a single institution, limiting generalizability, and lacked a control group, reducing the ability to make causal inferences. Its one-semester duration restricts understanding of long-term retention, while self-selection bias and potential Hawthorne effects may have influenced outcomes.

Based on these findings, recommendations include: for educators, implementing structured discussion methods with clear expectations, using diverse discussion formats, and managing time to balance depth and content coverage; for institutions, supporting faculty development in facilitation skills, recognizing active learning in teaching evaluations, and providing suitable classroom configurations; and for future research, conducting controlled experimental studies, investigating long-term impacts on professional competencies, exploring optimal discussion structures for different technical topics, and examining effectiveness across diverse vocational programs.

CONCLUSIONS AND RECOMMENDATIONS

This classroom action research demonstrates that the discussion method effectively enhances both student engagement and learning outcomes in Industrial Automation Systems education within vocational mechatronics programs. The substantial improvements in engagement (from 56.25% to 87.50%), learning outcomes (from 64.38 to 83.13), and mastery achievement (from 31.25% to 87.50%), coupled with 90.6% student satisfaction, provide compelling evidence for this pedagogical approach's effectiveness.

The discussion method's success stems from its alignment with active learning principles and social constructivist theory, creating learning environments where students actively construct technical knowledge through collaborative dialogue, peer explanation, and critical analysis. This approach not only enhances conceptual understanding but also develops essential professional competencies including communication, collaboration, and critical thinking—capabilities increasingly vital in contemporary industrial environments.

For vocational mechatronics educators, this research offers a validated, replicable model for implementing discussion-based instruction. While requiring careful planning and facilitation, the discussion method produces substantial educational benefits justifying the investment. As vocational education evolves to meet Industry 4.0 demands, pedagogical innovations emphasizing active learning, collaboration, and critical thinking become increasingly essential.

Ultimately, preparing competent vocational graduates capable of thriving in complex industrial automation careers requires moving beyond passive knowledge transmission toward engaging, student-centered pedagogies. The discussion method provides such an approach, fostering both technical expertise and professional competencies essential for success in the modern workforce.

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