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A MODEL-BASED APPROACH TO ENHANCING REFLECTIVE COMPETENCE OF FUTURE VOCATIONAL EDUCATION TEACHERS THROUGH INTEGRATED ENGINEERING AND LANGUAGE-BASED INSTRUCTION

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Abstract

The rapid digitalization of engineering-oriented vocational education requires future teachers to demonstrate not only technical knowledge but also reflective competence, enabling them to support adaptive decision-making and continuous professional development. This study aims to enhance the methodology for developing reflective competence among future vocational education teachers by integrating engineering disciplines and foreign language instruction. A mixed-methods research design was employed, including pedagogical modelling, experimental instruction, questionnaires, tests, and statistical analysis using t-test. The proposed approach integrates engineering subjects, such as vehicle technical operation and service, with language-based instruction to strengthen reflective thinking, self-assessment, and professional responsibility in engineering teaching contexts. Experimental results reveal a statistically significant improvement in reflective competence levels among students in the experimental group compared to those receiving traditional discipline-separated instruction. Interdisciplinary integration supported by model-based pedagogical frameworks effectively promotes reflective competence in engineering-oriented vocational education. This study contributes to engineering education research by offering a scalable and transferable methodological model for vocational teacher training programs aligned with contemporary engineering practice.

Keywords: Engineering education, Interdisciplinary integration, Professional training, Reflective competence, Vocational education.

1. Introduction

The ongoing transformation of engineering-oriented vocational education under the influence of digitalization, interdisciplinary integration, and global labour market demands has intensified the need for teachers who possess not only technical expertise but also well-developed reflective competence [1]. Many reports regarding vocational engineering have been reported [2-5]. In vocational engineering contexts, reflective competence enables future teachers to critically analyse engineering-based instructional decisions, evaluate professional performance, and continuously improve pedagogical practices in technologically complex learning environments [6-9]. International accreditation frameworks and engineering education standards emphasize reflective practice as a core component of professional competence required for sustainable engineering education.

Contemporary engineering education prioritizes not only the mastery of disciplinary knowledge but also metacognitive, self-regulatory, and adaptive abilities that support lifelong learning and professional autonomy. Within this framework, reflective competence is conceptualized as an integrative construct encompassing motivational, cognitive, activity-based, and reflective components. These components collectively facilitate the ability of future vocational education teachers to interpret professional experience, regulate pedagogical actions, and align instructional strategies with engineering practice and industry-oriented requirements. Research on reflective learning in higher education confirms that structured reflective processes significantly enhance analytical thinking, professional judgment, and competence development in engineering-related disciplines [10-12].

Recent empirical studies highlight the effectiveness of competence-based and interdisciplinary instructional models in engineering teacher education. Cluster-based education approaches, for example, have demonstrated measurable improvements in ICT competence among future computer science teachers by promoting collaborative problem-solving, applied engineering tasks, and reflective engagement with professional activities [13]. Similarly, pedagogical interventions grounded in engineering education principles have been shown to strengthen students' practical competence, analytical reasoning, and application of theoretical knowledge in engineering contexts [14]. Despite these advances, many existing studies lack explicitly visualized structural-functional and methodological models tailored to the formation of reflective competence in vocational engineering teacher training. Therefore, this study aims to enhance the methodology for developing reflective competence among future vocational education teachers by implementing a model-based approach grounded in interdisciplinary integration of engineering disciplines and foreign language instruction.

2. Methodology

This study employed a mixed-methods research design combining pedagogical modelling and experimental instruction to evaluate the development of reflective competence among future vocational education teachers. Detailed information regarding this method is explained elsewhere [15]. The participants were divided into control and experimental groups. The experimental group received integrated instruction combining engineering subjects, such as vehicle technical operation and service, with foreign language learning, while the control group followed traditional discipline-separated instruction. Data were collected using questionnaires, reflective competence tests, and observational instruments addressing motivational, cognitive, activity-based, and reflective components. Quantitative data were analysed using Student's t-test to determine the statistical significance of differences between groups, while qualitative observations supported the interpretation of competence development dynamics.

3. Results and Discussion

The development of reflective competence among future vocational education teachers was evaluated through a pedagogical experiment involving control and experimental groups. The assessment focused on four core components of reflective competence—motivational, cognitive, activity-based, and reflective - within an engineering-oriented vocational education context. The initial diagnostic stage confirmed that both groups demonstrated comparable reflective competence levels, with the majority of participants classified at low to medium levels, indicating limited capacity for systematic self-analysis, professional self-regulation, and engineering-based instructional reflection. Figure 1 illustrates the structural-functional model of reflective competence formation used as the conceptual foundation of the study.

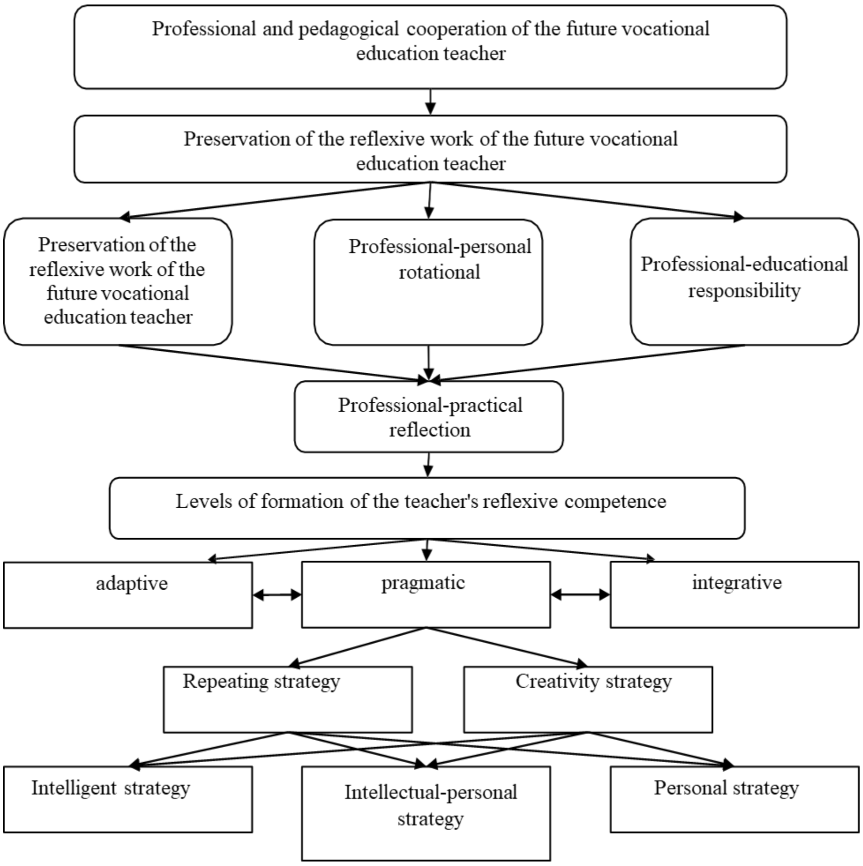

Fig. 1. Structural-functional model of reflective competence formation.

As shown in Fig. 1, reflective competence is conceptualized as a multidimensional system integrating motivational, cognitive, activity-based, and reflective components, operating across adaptive, pragmatic, and integrative levels. This model clarifies how reflective competence functions as a regulatory mechanism that links engineering knowledge, pedagogical decision-making, and professional responsibility. The progression across competence levels reflects increasing engagement with engineering-related instructional tasks, supporting the development of reflective strategies required for complex vocational teaching environments.

Following the implementation of the integrated instructional methodology, significant changes were observed in the experimental group. Students exposed to interdisciplinary integration of engineering subjects and foreign language instruction demonstrated consistent improvement across all reflective competence components. In contrast, the control group, which followed traditional discipline-separated instruction, exhibited only moderate gains, primarily within the cognitive component. These findings align with previous studies emphasizing that reflective competence develops most effectively within structured, competence-based learning environments that integrate engineering practice and pedagogical reflection [10, 12].

Figure 2 presents the methodological model for developing reflective competence through interdisciplinary integration applied in the experimental group. Figure 2 illustrates the alignment between goal-oriented, content-based, process-oriented, diagnostic, and outcome blocks within the instructional framework. The integration of engineering subjects, such as vehicle technical operation and service, with language-based instruction created pedagogical conditions that supported reflective thinking, professional communication, and self-evaluation in engineering teaching contexts. This structured methodological design operationalizes reflective competence development through clearly defined instructional stages and assessment mechanisms, extending existing interdisciplinary competence models in engineering education [16, 17].

Quantitative results further confirm the effectiveness of the proposed methodology. Table 1 presents the distribution of reflective competence levels in the control and experimental groups at the final stage of the experiment. The data in Table 1 indicate a substantial increase in the proportion of students achieving a high level of reflective competence in the experimental group compared to the control group. Specifically, more than half of the experimental group reached a high competence level, while the control group remained predominantly within the low to medium range. This shift reflects enhanced self-analysis accuracy, improved professional responsibility, and stronger adaptive decision-making abilities in engineering-oriented pedagogical situations.

At low angles of attack the normal force coefficients are in excellent agreement with the experimental data as shown in Fig. 3. This is expected due to the assumption of small angle of attack. The figure also shows that the current results are closer (average percentage error less than 0.5%) to the experimental data than those predicted analytically (average percentage error about 6%) by Saadi et al. [10]. This is expected as the analytical methods.

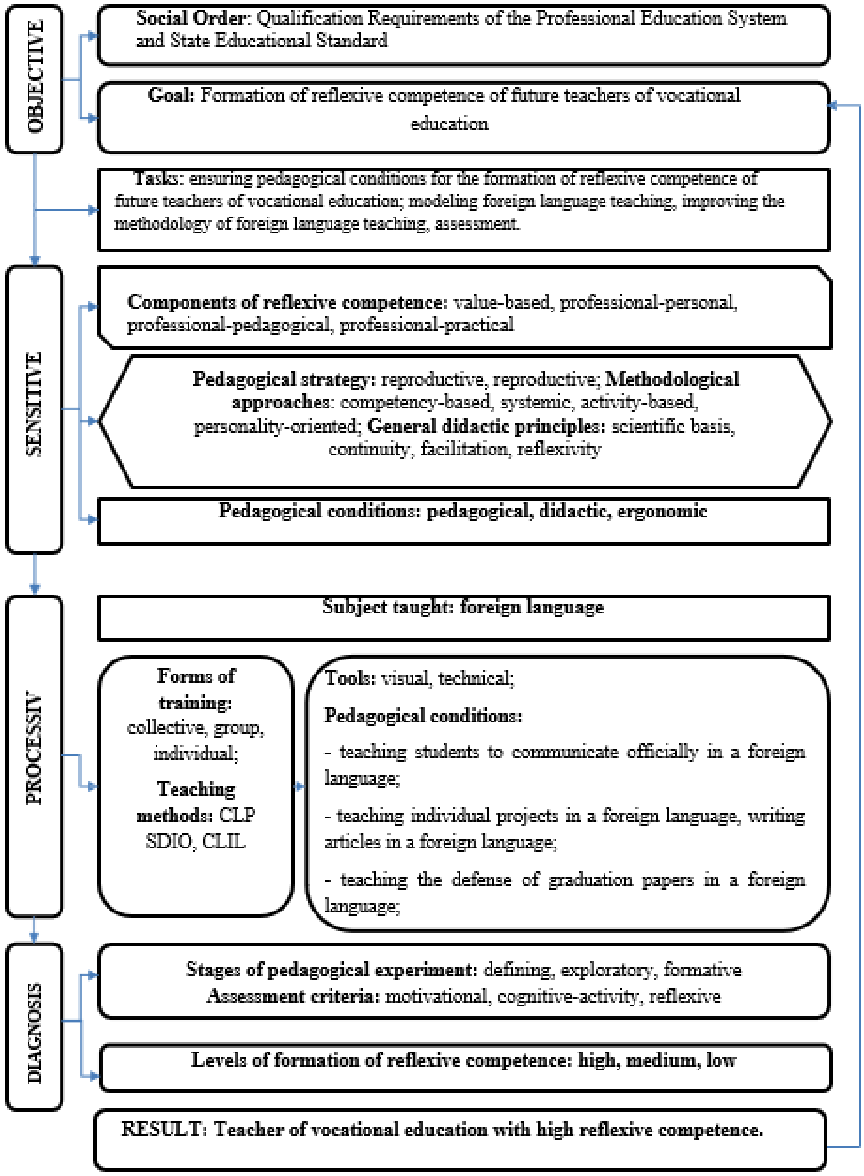

Fig. 2. Methodological model for developing reflective competence through interdisciplinary integration

Component-based analysis revealed that the most pronounced improvements occurred in the reflective and activity-based components. Students in the experimental group demonstrated greater capacity to evaluate engineering-based instructional decisions, apply technical knowledge in pedagogical contexts, and regulate their professional actions. Moderate yet statistically significant gains were also observed in motivational and cognitive components, indicating a holistic development of reflective competence. Statistical validation using Student's t-test confirmed that post-experimental differences between groups were significant across all assessed components ($p < 0.05$).

Table 1. Distribution of reflective competence levels (%)

Group	Low Level (%)	Medium Level (%)	High Level (%)
Control Group	32.4	48.1	19.5
Experimental Group	11.3	34.6	54.1

These findings are consistent with research highlighting the importance of interdisciplinary and competence-based instructional models in engineering teacher education. Cluster-based education frameworks have demonstrated similar outcomes by enhancing reflective engagement and applied problem-solving among future engineering teachers [13]. Moreover, pedagogical training grounded in engineering education principles has been shown to strengthen practical competence and analytical reasoning in engineering disciplines [14]. However, unlike prior studies that primarily focus on technical or ICT competence, the present research positions reflective competence as a central regulatory construct guiding professional teaching practice in vocational engineering education.

Overall, the results demonstrate that the proposed model-based and interdisciplinary methodology provides measurable advantages over traditional instructional approaches. By integrating engineering and linguistic competencies within a structured pedagogical framework, the study advances reflective competence research and offers practical implications for vocational institutions seeking to align teacher preparation with contemporary engineering education standards.

4. Conclusion

This study confirms that reflective competence is a fundamental professional attribute for future vocational education teachers within engineering-oriented learning environments. The findings demonstrate that reflective competence can be effectively developed through a model-based pedagogical framework integrating engineering disciplines and language-based instruction.

The proposed structural, functional, and methodological models provide a systematic approach to strengthening reflective thinking, self-regulation, and professional responsibility in engineering teaching contexts. Empirical evidence indicates that the integrated instructional approach yields significantly higher reflective competence levels than traditional discipline-separated instructions.

These results contribute to engineering education research by offering a transferable methodology for vocational teacher training aligned with contemporary engineering education standards and professional practice requirements.

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