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Effect of ISIED Education Activities on The Development of Students' Key Competency

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Abstract: Since the 21st century, countries and regions have regarded collaborative learning, critical thinking, creative thinking, and problem-solving skills as key competencies for students. Teaching methods with integrated multidisciplinary approaches, akin to STEM education, are emphasized to create real-world problem scenarios for students and integrate engineering practices with science teaching into traditional science curricula. However, teachers in science courses often overlook engineering practices, and there is currently a lack of an operational educational model to support the integration of engineering practices into the classroom. This study improves and optimizes the STEM teaching model, integrating scientific inquiry and engineering design. Taking the science teaching unit "Heat" as an example, it designs a course to explore the impact of the ISIED educational activities on students' key competencies. The results indicate that the ISIED educational activities promotes students' understanding of scientific concepts and the application of knowledge in real-world problem-solving, thereby advancing the development of 21st-century key competencies.

Keywords: Key Competency, Collaborative Learning, Critical Thinking, Creative Thinking, Problem Solving Ability, Science Education, ISIED

1.Introduction

Cultivating students' key competency is central to 21st-century global science education, with integrating engineering practices a reform focus. The U.S. integrates scientific and engineering practices under STEM, but localized implementation often isolates them due to educators' limited engineering design experience, hindering problem-solving development. Yet engineering design is irreplaceable for scientific learning and key competencies (Wendell & Rogers, 2013), and comprehensive integration models are lacking.

The U.S. promotes integrating K–12 engineering-science instruction via STEM. NGSS (2013) highlight engineering design's interdisciplinarity and role in problem-solving, spurring related studies. Kolodner et al. (2003), Wendell and Rogers (2013), and Siew et al. (2016) showed engineering design enhances reasoning, collaboration, science learning, creativity, and problem-solving. But Crismond and Adams (2012) note integration challenges for non-engineering teachers, requiring feasible models. English et al. (2017) propose a five-phase sequence: problem scoping, ideation, design & prototyping, evaluation, and redesign/reconstruction, where interdisciplinary STEM knowledge is intentionally included.21st-century key competency frameworks (Bruxvoort & Jadrich, 2016) stress their integration.

This study optimizes the model by integrating scientific inquiry and engineering practice, creating the "Integrated Scientific Inquiry-Engineering Design (ISIED) STEM Instructional Model" (Figure 1).

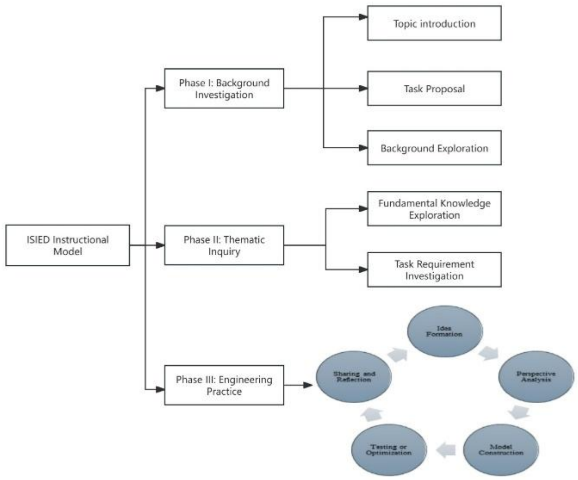

Figure 1. ISIED Instructional Model

The ISIED model, an optimized STEM update centered on engineering problem-solving, retains the original three-phase structure: Phase I (Background Investigation) emphasizes authenticity in three progressive components to lay the groundwork for inquiry and design; Phase II (Thematic Inquiry) links scientific inquiry and engineering practice via theme-centered investigations to foster teamwork and critical thinking; Phase III (Engineering Practice) is an iterative cycle for applying knowledge and collaboration capabilities, with engineering design spanning all phases. Unlike traditional science classes, ISIED adopts an investigation-inquiry-design approach aligned with key competency cultivation, assessing progress in applying knowledge rather than just knowledge acquisition or product quality.

Though optimized from the "STEM model with engineering problem-solving as the main thread," ISIED’s application in science classrooms and its ability to promote students' 21st-century key competencies and scientific knowledge need verification, forming the study’s main research questions:

RQ1: Does the ISIED instructional model enhance students' scientific knowledge acquisition?

H1: Students participating in ISIED educational activities will demonstrate significantly more significant improvement in scientific knowledge compared to the control group.

RQ2: Does the ISIED instructional model improve students' collaborative learning, critical thinking, problem-solving abilities, and creative thinking?

H2: Students participating in ISIED educational activities will exhibit significantly enhanced collaborative learning skills compared to the control group.

H3: Students participating in ISIED educational activities will show significantly greater development in critical thinking compared to the control group.

H4: Students participating in ISIED educational activities will have significantly superior problem-solving capabilities compared to the control group.

H5: Students participating in ISIED educational activities will demonstrate markedly higher levels of creative thinking than those in the control group.

2. Method

This study used a quasi-experimental pre-test/post-test design, with 20 fifth-graders in Classes 1-3 (experimental group, ISIED activities) and 20 in Class 4 (control group, traditional science courses) matched by prior science scores. It ran two weeks (60-minute sessions) through pre-test, intervention, and post-test stages. Tools included a science knowledge questionnaire, 21st-Century Key Competencies Scale (Cronbach’s α=0.95), and post-test semi-structured interviews.

3. Results

Paired t-tests on heat transfer knowledge showed both groups improved, with the experimental group (t=12.499, p=0.000, d=2.281) gaining more than the control group (t=3.627, p=0.002, d=0.978). ANCOVA (covarying pre-test) confirmed the experimental group's post-test scores remained higher, supporting Hypothesis 1 that ISIED better enhances scientific knowledge.

For key competencies, paired t-tests found the experimental group improved significantly in total scores (t=2.454, p=0.024, d=0.530), collaborative ability (t=2.680, p=0.015, d=0.557), and critical thinking (t=2.320, p=0.032, d=0.618). ANCOVA (Table 4) showed their post-test total scores (F=6.69, p=0.014) and collaborative/critical thinking scores (F=2.952, p=0.094) outperformed the control group, supporting Hypotheses 2 and 3. However, no significant improvements were seen in creative thinking (t=1.774, p=0.092, d=0.391) and problem-solving ability, though interviews indicated ISIED improved problem-solving, supporting Hypotheses 4 and 5.

Student interviews revealed positive feedback, with the unit seen as "fun" and "engaging" compared to traditional lessons. Students noted more active knowledge construction, stronger collective responsibility, and highlighted the focus on real-world engineering practice, recognizing improvements in collaboration, critical thinking, and creativity.

4. Discussion

This study explored ISIED activities' impact on students' scientific knowledge and key competence, drawing main conclusions: ISIED effectively enhanced scientific knowledge (consistent with Wendell & Rogers, 2013; Cunningham et al., 2020) via inquiry-engineering approaches and real-world context, and promoted collaborative learning and critical thinking (supporting Kolodner et al., 2003). However, it had no significant impact on creative thinking and problem-solving (contrary to Siew et al., 2016) due to short duration, weak creativity perception, and inertia, with recommendations including documenting creativity and teaching strategies. Unexpectedly, traditional courses failed to improve key competence and lowered scores, lacking real-world problems and independent decision-making.

This study has limitations affecting applicability: small sample size (20 per group) restricts generalizability, with group assignment via prior scores possibly misreflecting current skills; a two-week intervention too short for competency building; self-reported key-competency data may be biased.More focused studies are needed.

References

Adams, R. (2012). The informed design teaching and learning matrix. Journal of engineering education.

Bethke Wendell, K., & Rogers, C. (2013). Engineering design‐based science, science content performance, and science attitudes in elementary school. Journal of Engineering Education, 102(4), 513-540.https://doi.org/10.1002/jee.20026

Bruxvoort, C., & Jadrich, J. (2016). DON'T" SHORT CIRCUIT" STEM INSTRUCTION: Exploring the goals of engineering and science. The Science Teacher, 83(1), 23-28.https://doi.org/10.2505/4/tst16_083_01_23

Cunningham, C. M., Lachapelle, C. P., Brennan, R. T., Kelly, G. J., Tunis, C. S. A., & Gentry, C. A. (2020). The impact of engineering curriculum design principles on elementary students' engineering and science learning. Journal of Research in Science Teaching, 57(3), 423-453.https://doi.org/10.1002/tea.21601

Kolodner, J. L., Gray, J., & Fasse, B. B. (2003). Promoting transfer through case-based reasoning: Rituals and practices in learning by design classrooms. Cognitive Science Quarterly, 3(2), 183-232.

NGSS Lead States. (2013). Next generation science standards: For states, by states. National Academies Press.

Siew, N. M., Goh, H., & Sulaiman, F. (2016). Integrating STEM in an Engineering Design Process: The Learning Experience of Rural Secondary School Students in an Outreach Challenge Program. Journal of Baltic Science Education, 15(4), 477-493.https://doi.org/10.33225/jbse/16.15.477