

A MODEL FOR ASSESSING XXI CENTURY COMPETENCIES IN THE CONTEXT OF PROBLEM-BASED LEARNING

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Abstract

The article presents a model for integrating XXI century competencies into summative assessment through the application of Problem-Based Learning (PrBL). It presents a conceptual framework based on an adapted version of the World Economic Forum framework, which combines traditional knowledge assessment with the evaluation of key XXI century competencies. The framework includes four groups of competencies: Cognitive – critical thinking, problem solving, creativity; Social-emotional – collaboration, communication, ethics and social responsibility, global awareness, intercultural sensitivity; Personal – self-regulation, self-confidence and adaptability, initiative and entrepreneurship, lifelong learning; Transversal – digital competency. Depending on whether the relevant competency is acquired as a targeted result or as a secondary effect of the educational process, competencies are systematized into two subcategories: explicit, which manifest themselves as planned outcomes and a transition from conscious incompetency to conscious competency, and implicit, which arise as significant secondary outcomes for the personal and social development of students. The framework offers the possibility of integrating key competencies into specific criteria for assessing mathematical problems, but its structure allows for adaptability to different disciplines and educational contexts. When expanded with achievement indicators and a rating scale, the framework can be transformed into a meaningful rubric. In conclusion, the importance of competency-oriented frameworks as a means of synchronizing traditional educational content with contemporary educational requirements is emphasized, with an accent on the need for future testing of implicit socio-emotional competencies in a real school context.

Keywords: *Problem-based learning, formative assessment, summative assessment, XXI century competencies, conceptual framework for competency assessment.*

1. Introduction

Contemporary education is faced with the challenge of preparing students not only with knowledge but also with competencies key to the personal and professional development of individuals for the 21st-century – critical thinking, collaboration, creativity, digital literacy, and lifelong-learning competencies (Soffel, 2016). Traditional summative assessment often focuses primarily on measuring acquired knowledge, but in the context of new educational paradigms, it is necessary to integrate tools for assessing competencies as well. In this context, Problem-Based Learning (PrBL) is an approach that naturally falls under the competency model. Competencies are built most effectively through solving real-life problems where students apply knowledge in authentic situations, make decisions, and work in a team. Therefore, PrBL is not only a method for acquiring educational content but also a context in which 21st-century competencies are developed and can be assessed. According to Sistermans (2020), PrBL, where students actively explore real problems, can promote critical thinking and collaboration in learning. It can also stimulate students' creativity, adaptability, curiosity, sense of responsibility, and perseverance. Other studies (Kahila et al., 2020) show that project-based learning environments foster emotional and social skills for coping with negative emotions and collaborating with other students to achieve a common goal (Alt et al., 2023). In this context, the assessment of competencies emerges as a key element that forms the foundation of modern pedagogical approaches. For teachers to be able to accurately assess students' progress, it is necessary to create specific, measurable, and clear criteria for evaluating developed competencies. Unlike summative assessment, which emphasizes the final result and where feedback is most often given in the form of a grade, formative assessment directs attention to the learning process and the opportunities for its improvement. The process can be defined as the purposeful and systematic provision of feedback during the learning process, which stimulates the acquisition of knowledge and supports the development of key competencies. Its effectiveness is realized when the information from the feedback is

actively integrated for adapting pedagogical practices actively and by the learners for regulating their own learning and improving achievements. According to Seidl (2024), an advanced approach to formative assessment is an essential element of the overall concept for integrating modules oriented towards 21st-century skills and not only supports the individual learning journey of students but also contributes to the purposeful development of key competencies. The goal of the present study is to develop a conceptual model for creating rubrics that track the entire process of evaluating project-based learning outcomes – from formulating specific criteria for summative assessment and the role of formative assessment in this process, to integrating competencies into specific assessment criteria.

2. Materials and methods

The competency framework of PrBL (Kirilova, 2024), based on the widely applied framework of the World Economic Forum, serves as the basis for developing the model. The proposed framework could be used as an instrument for summative assessment of developed competencies resulting from solving a specific mathematical problem. For the purpose, four groups of competencies are distinguished: cognitive (critical thinking, problem-solving, creativity), social-emotional (collaboration, communication, ethics and social responsibility, global awareness, intercultural sensitivity), personal (self-regulation, self-confidence and adaptability, initiative and entrepreneurship, lifelong learning), and transverse (digital competency). According to (Howell, 1982), the learning process consists of four stages: Unconscious incompetency; Conscious incompetency; Conscious competency; Unconscious competency. Learning processes begin with the realization of what we already know and can do on the one hand, and what we do not know/cannot do on the other hand. This step facilitates the transition from unconscious to conscious incompetency, enabling learners to identify gaps in knowledge and competencies and to gain clarity about their individual learning needs. (Seidl, 2024). In the process of working on authentic tasks, a transition from conscious incompetency can usually be made, but sometimes, along with the purposefully intended competencies, implicit competencies are also formed. Depending on whether the relevant competency has been acquired as a deliberate outcome or as a secondary effect of the educational process, the competencies are systematized into two subcategories: explicit, which manifest as planned outcomes, and implicit, which the author suggests have the potential to emerge as significant secondary outcomes for students' personal and social development. The developed structure is applied as a tool for formulating specific criteria for assessing a mathematical problem, but at the same time, it maintains adaptability to different disciplines and educational contexts. In addition, by including achievement indicators and a rating scale, the framework can be transformed into a complete rubric, providing a reliable and valid basis for summative assessment.

Mathematics Project Problem: Data analysis on the use of digital devices among students.

Task formulation: Students work in teams of 2–3 participants and are required to select and analyze real statistical data on the frequency and methods of use of digital devices by students aged 14–18 in different countries, using reliable and correctly cited sources.

Work stages: 1. Sample formation – selection of a representative sample of at least 150 students from a minimum of three countries, presenting arguments regarding the selection method used. 2. Organizing the data – entering the collected data in tabular form (e.g., Excel or Google Sheets) and arranging the values in order of variation. 3. Statistical processing – calculating indicators of central tendency (mean, median, and mode). 4. Data visualization – preparation of appropriate graphs and/or charts, provided with a clearly formulated title and legend. 5. Analysis and interpretation – comparing the results between countries and identifying similarities and differences based on the statistical indicators obtained. 6. Presentation – presenting and discussing the results in front of an audience, with reference to the data and sources used.

Table 1. Model for Summative and Competency Assessment of PrBL.

Criteria	Role of Formative Assessment	Area of Explicit Competency	Area of Implicit Competency
Sample Formation	Feedback on sample validity and responsible use of data	Digital competency: Use of digital tools, critical evaluation of online sources, protection of personal information	Ethics and social responsibility – responsible use of data, respect for anonymity and protection of personal rights. Ethics and social responsibility in digital environments.
Correctness of Mathematical Calculations	Guiding towards precision of calculations and justification of solutions	Critical thinking and problem-solving: Problem identification, information analysis, making informed decisions	Global awareness – understanding the influence of digital devices on learning and daily life in a social and international context
Presentation of Results	Feedback on visualization choice and encouraging clear presentation	Digital competency	
Data Analysis	Feedback on the accuracy of the analysis and the logic of the conclusions	Critical thinking	
Teamwork	Assessment of collaboration effectiveness and communication	Teamwork, active listening, presentation of ideas	Intercultural sensitivity – respect for differences and constructive dialogue in a team with diverse participants
Presentation and Defense of Conclusions	Focus on persuasiveness, clarity, and argumentation	Communication, creativity: generating innovative solutions, building upon ideas	Self-confidence and adaptability – confident presentation of the results and reasoning-based defense of conclusions
Reflection on the Process	Support for the development of self-regulation and motivation through self-assessment and feedback	Lifelong learning, Self-regulation: self-motivation, application of knowledge, seeking feedback	Initiative and entrepreneurship – process organization, time management, and taking on leadership roles

3. Discussion

The organization of learning activities, including teamwork, presentation and defense of conclusions, as well as reflection on the learning process, creates conditions for the implicit development of a wide range of competencies that go beyond the cognitive outcomes traditionally associated with mathematics education. Teamwork requires interaction between learners with different perspectives, strategies, and communication styles, which implies respect for differences and maintaining a constructive dialogue. In this sense, intercultural sensitivity manifests itself as a natural result of the social dynamics of joint problem solving, rather than as a pre-set educational goal. Presenting and defending conclusions puts learners in situations where they have to formally present and justify decisions, which requires adapting their arguments to the audience and context. These activities support the development of self-confidence and adaptability in communication through clear structuring of ideas, logical consistency, and adaptation of arguments in response to questions and feedback. Reflection on the learning process further engages learners in planning, self-observation, and evaluation of their own activities, thereby supporting initiative, entrepreneurial thinking, and the assumption of responsibility and leadership roles within the learning environment. The requirement to verify mathematical results obtained through digital means transforms the use of technology from an instrumental to an analytical level. This engages learners in critically reflecting on the relationship between algorithmic processing and mathematical meaning, as well as analyzing the limitations arising from algorithms, input data, and the epistemological frameworks of digital computation. In this sense, the accuracy of calculations functions as a mechanism for forming a responsible and informed position towards automated data processing systems. The process of forming a data sample further reveals the ethical and social dimensions of statistical activity. Decisions related to the selection of participants, scope, and representativeness of data require responsible use of information, respect for anonymity, and protection of personal rights. From this point of view, activities related to the collection, processing, and interpretation of statistical data have both analytical and educational significance in terms of the formation of ethical and social responsibility. The explicit requirement for correct citation of the data and sources used is essential for the formation of implicit competencies related to ethics, responsibility, and scientific culture when working with information. In educational practice, it is often observed that even at university level, students do not always cite the sources they use, which indicates a persistent deficit in information

literacy and understanding of the ethical dimensions of working with data. In this context, the systematic introduction of referencing and citation practices as early as in school, is in line with the European Digital Competence Framework 2.2 (Vuorikari et al., 2022), which describes the knowledge, skills, and attitudes necessary for the effective, critical, and responsible use of digital technologies and information. In this way, the addition of information sources goes beyond its role as a formal academic requirement and functions as an educational mechanism for developing ethical sensitivity, respect for intellectual work, and social responsibility in a digital environment.

In summarizing, the proposed model for integrating 21st-century competencies into summative assessment rubrics shows that even traditional mathematical tasks, such as problem solving, can be conceptually expanded to encompass social-emotional and personal dimensions of learning. In line with the vision of the OECD (2019, 2023), which considers social and emotional competencies as a separate but interrelated category alongside cognitive and practical skills, the model supports a holistic approach to competency-based assessment without compromising the disciplinary rigor of mathematics.

4. Conclusion

The differentiation into explicit and implicit competencies creates a basis for more reliable tracking of the different aspects of student development, complementing the research of Durlak et al. (2015), who emphasize that effective assessment of social-emotional skills (SEMS) requires clear, evidence-based standards and criteria, as well as curricula that combine formative and summative approaches to track and stimulate student progress. At the same time, as Pancorbo et al. (2021) note, social-emotional rubrics must be applied with increased caution, as they do not always provide sufficiently reliable information for making high-stakes decisions for students within summative assessment. The applied example of a mathematics project task and the proposed framework illustrate how, through synergy between traditional summative assessment criteria and additional indicators, a more objective assessment of competencies can be achieved, thereby offering a solution to overcome some of the limitations of social-emotional rubrics by combined indicators for explicit and implicit skills applicable across various disciplines. However, at this stage, empirical testing is lacking for some of the social-emotional competencies, which is why they are assigned to the implicit group, while the others, for which indicators have already been developed and tested, are included among the explicit ones. Future research should focus on validating the indicators in real-life learning environments and checking the applicability of the rubric in different educational contexts.

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