Pre-Service Teachers' Perspectives on and Strategies for Assessment of Computational Empowerment-based Projects

Assessing Critical, Creative, and Project-Based Approaches to Digital Literacy

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Abstract
Young learners today find themselves in an increasingly complex and digitalized world. Accordingly, educational research, policy and practice need to develop and implement modern frameworks and approaches that foster critical and self-determined engagement with corresponding challenges. Computational Empowerment (CE) represents a recent development in response to this need. It applies ideas inherent to participatory design and constructionist learning in order to promote digital literacy and a creative, hands-on approach to engaging with digital technology. Despite its proven potential, CE has yet received little room in formal education. This paper focuses on two key problems in this regard: difficulties with assessment and the limited role of CE in teacher education, both of which hinder its adoption in schools. To explore these issues, the paper analyzes 17 student reflections on assessing CE-based projects. It examines students' assessment strategies, including criteria, methods and challenges. Based on the findings, the paper highlights key challenges and, consequently, proposes strategies for advancing CE in formal education.

Keywords and Phrases: Computational Empowerment, Assessment Methods, Teacher Education, Digital Literacy

1. Introduction
The principles of constructionism have shaped technology-related education for decades. Given the increasing emphasis on fostering digitally literate, self-directed, and active learners, these ideas are more relevant than ever. Learning approaches to digital literacy education continue to build on constructionist foundations. One such approach, Computational Empowerment (CE), builds on the construction and deconstruction of technologies embedded in everyday life as a means to enhance digital literacy. CE promotes critical, co-constructive, and creative learning by combining insights from participatory design (PD) research with technology education (Dindler et al., 2020; Iversen et al., 2018).

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Despite the rich histories of PD- and constructionism-based learning in educational research, integrating design-based, self-directed approaches into the often rigid structures of formal education remains challenging. Obstacles include the need for more flexible assessment methods, limited time resources, difficulties in aligning with curricula, and insufficient teacher training (Göbl, Duvivié, et al., 2023; Kaspersen et al., 2021; Veldhuis et al., 2023).

This paper presents a case study situated in a bachelor's course for teacher students. Students develop learning concepts and implement prototypes for CE-based projects in class and, subsequently, build on the course experience to reflect on potential assessment strategies and their challenges in writing. A qualitative analysis of these reflections allows first insights into their perspectives on CE-related assessment. The paper zooms in on findings and next steps with regard to assessment practices and CE in teacher education. The following research questions are addressed:
1. What assessment strategies do pre-service teachers consider based on their practical experience with self-developed, CE-based projects?
2. What challenges do pre-service teachers identify regarding assessment and implementation of CE-based projects?

The paper first provides some background on CE and respective issues in its application and assessment in formal education. Subsequent sections outline methodology, results and, finally, discuss the implications of the findings presented.

2. Background

Computational Empowerment describes a recent approach to fostering digital literacy, that encompasses creative and self-determined construction and deconstruction of technology. Construction processes draw on the ideas of participatory design and emphasize co-constructive, critical approaches to the design of digital technology (Dindler et al., 2020; Iversen et al., 2018). Tightly linked to the constructionist philosophy (Göbl, Guenther, et al., 2023), CE suggests a process model for knowledge and artefact construction, that encompasses initial design briefs and research, ideation and construction, and subsequent reflection and argumentation (e.g. for design choices) (Iversen et al., 2018). Early reports of CE-based interventions often focus on Maker-related projects, however, CE's ideas have since been successfully applied in a range of technology-related learning fields such as game-based learning (Weixelbraun et al., 2024)corresponding competencies are required from children more than ever. The concept of computational empowerment (CE, learning with and about artificial intelligence (Schaper et al., 2022) or entrepreneurship education (Hartikainen et al., 2023). Its many potentials for young learners encompass not only digital competency building but emphasize the development of active, critical stances towards technology development and its role in our lives. Yet, despite its many potentials, several hurdles remain in the adoption of CE in formal education.

For one, CE suffers from resource issues both related to time and teacher education. Creative, self-directed learning is often a difficult fit for tight school schedules, due to its demand on flexibility and self-exploration (Ingold & Maurer, 2019). To a large extent, previous research in participatory design in school has often looked at projects that take place outside of regular school hours (Göbl, Duvivié, et al., 2023), leaving scheduling conflicts and time-related issues unaddressed. Further, measurements and assessment of CE still pose an issue. Many of its inherent goals have hitherto not been operationalized and are hard to fit into contemporary grading systems.

Adaptations of project- and design-based learning and their methods, such as portfolio-based assessments, may fail to address key elements of CE, such as adoption of new attitudes, and are also resource-intensive, requiring additional training for teachers (Göbl, Duvivié, et al., 2023; Lam, 2019). This paper aims to further explore assessment in the field of CE by analyzing teacher students' reflection on their practical experience with CE-based learning in the course.

3. Methodology

This section details the collection and analysis of teacher students' reflections on CE-based assessment. The approach aimed to consider issues arising from the author's dual role as course instructor and researcher. To address ethical concerns, measures to decouple consent for data analysis and grading were explicitly communicated to students (see below), and the task descriptions for the analyzed work were primarily aligned with the course's learning objectives and, secondarily, with the research goals outlined above. Consequently, the analysis combined inductive elements with deductive ones, the latter informed by specific topics embedded in the task descriptions, as further explained below.

3.1 Data Gathering

All analyzed texts were part of a writing task for the course "Designing with and of Digital (Educational) Technology" in the fall/winter term of 2023/2024. The course is part of the general Bachelor's curriculum for pre-service teachers at the Centre for Teacher Education at the University of Vienna and is typically taken in the fourth semester. Teacher students from diverse subject backgrounds attend the course. All course participants received a detailed consent form to make an informed decision about whether they agreed to the analysis of their data. It was repeatedly communicated orally and in writing that consent did not impact grading. To further ensure voluntary participation, students were allowed to withdraw consent up to two months after grading. For this study, 19 students agreed to the analysis of their reflections. No specific information on age or gender was collected. In classroom discussions at the beginning of the semester, students did not report any previous experience with project-based or similar work from a teacher's perspective.

The course is structured around the Computational Empowerment (CE) process model, guiding students through different stages of the design process: (1) design brief, (2) research, (3) ideation, (4) construction, (5) reflection, and (6) argumentation. The course introduces students to digital fabrication, gaming technologies and educational robotics (e.g., 3D printers, laser cutters, Nintendo Switch consoles, Micro:Bits, or LEGO Mindstorms) and explores CE-based applications thereof for school. Students worked in groups of 3-5 people to devise interdisciplinary projects, including learning goals and instructions, that allowed for active knowledge construction according to CE and constructionist principles. Projects needed to include at least one of the offered fabrication or educational technologies and followed the CE process model. Accordingly, students iteratively developed prototypes and teaching concepts: First, they discussed relevant learning goals and potentials tasks integrated in their project based on their subject-background and interests. Then, they researched projects and facts related to their chosen technologies and learning content. Further, they brainstormed ideas for implementation and iteratively refined sketches and constructed material prototypes. The learning process was documented by each group through posts in an online forum open to all course participants and through oral presentations.

The analyzed texts were part of a writing task situated at the end of the semester. Teacher students had to reflect on their perspectives of successes and failures regarding their project work and discuss how they would approach assessment of similar projects in their future classroom. The written reflections primarily focused on summative assessment of learning (i.e. assessment *of* learning) rather than formative assessment which aims to support learning processes (i.e., assessment *for* learning, see Black & Wiliam (1998)). Considerations on assessment criteria and what data or artefacts to base this on were explicitly asked for. Two non-mandatory readings (Ingold & Maurer, 2019; Pang, 2016) were provided as orientation. While projects were developed in groups, the analyzed texts were written as individual assignments.

3.2 Analysis

Nineteen students submitted reflections on assessment for their group projects and consented to the analysis of their works. One reflection was excluded due to the student admitting that it was partly written by generative AI and another reflection was excluded due to the student not addressing the prescribed topic. A total of 17 reflection papers were analyzed using reflexive Thematic Analysis (rTA) (Braun & Clarke, 2022). This method does not aim to result in "accurate" or "reliable" coding but rather builds on engagement with the data in a reflective and thoughtful manner (Byrne, 2022). The analysis followed an iterative approach as prescribed by the method: While the author was already familiar with the data due to grading tasks, the texts were read again to re-familiarize with a new focus based on the research aims. Next, inductive and deductive coding was conducted, partly based on categories that were addressed in the task description ("assessed artefacts" and "assessment criteria" were explicitly asked to be addressed) and partly oriented on categories emerging from the texts by systematically identifying meaningful segments. These codes were then examined for patterns and grouped into emerging themes in several iterations, capturing key aspects of the participants' reflections.

4. Results

Students discussed several challenges and general considerations for assessment in CE-related projects, ranging from difficulties with prospective learners developing individual projects to stating that assessment for these projects differs from what they usually learn in their studies. As instructed, students considered assessment criteria. This encompassed cross-curricular, subject-specific or other, e.g. formal criteria, in their reflections. Next to listing concrete assessment criteria, students also reflected on factors impacting assessment schemata, such as curricular goals or the need to look beyond that and assess cross-curricular competencies. According to the task instructions, students discussed assessed artefacts and data but also included several further considerations in this regard, resulting in below outlined analysis of assessed artefacts and reasoning. Table 1 provides an overview of identified themes, subthemes and includes exemplary quotes to clarify corresponding codes.

Theme	Sub-theme	Code	Exemplary Quote(s)
Challenges and General Consider-ations for Assessment	Challenges for Assessment	Individual solutions to tasks	“This assessment is much more complex, as the selection of topics is very subjective” “However, it should be added that there is not just one correct way to code the required program.”
		Different to other Assessment Methods	“Personally, I find it challenging to carry out the assessment using the ‘conventional’ assessment system prescribed by the education system and curriculum.”
	Competency-Based Assessment	Adapting Assessment for modern learning	“Especially nowadays, with the measurement of competencies, the proportion and importance of doing things yourself is increasing. The aim is for pupils to learn skills so that they can use them again and again in various situations.”
Assessment Criteria	Cross-curricular competencies	Problem Solving/ Learning From Failure	“There will almost certainly be errors in the development of the project. However, these should not be seen as negative. At best, they will be recognized through feedback during the work process and then corrected or further processed. The way in which errors are dealt with should also be included in the assessment.” “Error analysis and inclusion in the final presentation are also very important”
		Creativity	“I would also like to consider the aspect of creativity. Does the solution found allow you to recognize your own approaches and considerations? How much experimentation was done within the given framework?”
		Teamwork	“In this project, it is important to work with classmates and get involved. Accordingly, the first assessment point is successful cooperation in a group.”
	Other Criteria	Functional Aspects of Prototype	“In the first phase, it is possible to assess whether the code works and whether all key points have been met.
		Formal Criteria (Completeness, Timely submission)	“Another approach to evaluating the project could simply be whether tasks were completed, which means to not consider the quality of the end products.”
		Effort and Motivation	“Not only the ability, but also the efforts of the learners should be taken into account and included in the assessment, whereby the ability should only be regarded as secondary.”
Factors Impacting Assessment Schemata		Curricular Goals	“Curricular requirements play a decisive role in the assessment. These define the learning objectives and competencies that are to be achieved through the project” “[...], the project should have a clear link to the curriculum, which means that curricular guidelines are already binding during assessment”
		Need to Address Cross-Curricular Goals	“Even if the school system always demands a curriculum reference and often concretely measurable skills, it should also be possible to include so-called soft skills in the assessment, especially for more creative projects, and to open up scope in the rigid school system”

Theme	Sub-theme	Code	Exemplary Quote(s)
Assessed Artefacts and Reasoning	Assessed Artefact/ Evidence (What evidence is used for assessment?)	Presentations	"In addition, the presentation of the groups functions as a further artifact that makes the intensity of the engagement with the respective topic visible." "The presentation given at the end of our project should also be included in the assessment. In this, they should share their learning experience and can justify their work to a certain extent.
		Observations	"As this is a group project, each participant should make a contribution and do their best. The teacher should recognize and note this through observations during the project."
		Prototypes	"Another aspect that would be included in the assessment would be the quality of the artifacts" "Prototypes or models, which are physical or digital representations of the project result, also play an important role."
		Documentation and written Reflections	"The documentation of the process is also of great importance for the assessment, as the teacher thus has a written record of the considerations, information and findings." "However, because I also consider awareness of one's own work process to be a relevant competence, I would have the students themselves record these aspects in the context of discussions, peer feedback or reflections/documentation"
		Accompanying work sheets	"[...] the output consists of various worksheets and assignments that the students work on while playing. An assessment could possibly be made on the basis of the creativity of the work assignments and the degree of integration of the Nintendo Switch, whereby it must also be mentioned that the worksheets we created are again based on the curricular learning goals and competence specifications of the educational plans"
	Arguments for Artefact/ Evidence (Why is it used?)	Why Documentation?	"The documentation of the process is also of great importance for the assessment, as the teacher thus has a written record of the considerations, information and findings."
		Why Presentations?	"The presentation given at the end of our project should also be included in the assessment. In this, they should share their learning experience and can justify their work to a certain extent."
		Why Peer Assessment?	"This feedback helps to look at the project from different perspectives and develop new ideas. It also encourages the sharing of know-how, ideas and solution sets."

Table 1: Themes, Sub-themes, Codes and Exemplary Quotes

5. Discussion

The 17 analyzed papers provide noteworthy insights into students' strategies and corresponding obstacles when assessing CE-based projects. The following section discusses core findings and their implications for researchers, teacher educators and practitioners aiming to promote CE in formal educational settings.

Students value effort, subject-specific, and cross-curricular competencies

Both subject- and cross-curricular competencies have been considered by students and identified as competencies that should not only be part of assessment but are likely fostered by their implementations of CE-based learning concepts. Thus, the analyzed texts reflect a contemporary understanding of education that looks beyond acquisition of subject-related skills and knowledge (OECD, 2020). This provides yet another strong argument towards the integration of CE in formal educational contexts or, as a prerequisite, teacher education. Several competencies that are part of CE's agenda including digital literacy and fostering active participation in technology development (suggested by several considerations to include effort or motivation as assessment criteria) are reflected in the analyzed texts. However, CE's inherent ideas of fostering sustainable, active and critical stances towards digital technology and its development have not been reflected on by students in these works. Further investigation into the reasons for this is necessary in order to examine if pre-service teachers consciously did not consider these goals for assessment, did not see them related to their tasks as teachers or simply did not consider to assess this.

Students acknowledge the value of CE but are not familiar with teaching and assessing such projects

As outlined above, several aspects related to CE seem to be valued by students and are considered for integration into assessment strategies of their designed projects. However, some reported issues and difficulties show that CE and related ideas are still new territory for teacher students. For example, teacher students expect difficulties when assessing works where their prospective students can develop individual solutions to the task. This was stated as a major hurdle in their assessment considerations. Some students explicitly mention that they are not familiar with assessment methods they would consider appropriate for CE-based projects, and they think it is not taught or promoted in their subject-specific studies. These arguments are supported by many previous works that outline the frictions between constructionist ideas, design-based, and participatory learning and requirements and practices in formal education (Göbl, Duvivié, et al., 2023; Ingold & Maurer, 2019; Könings et al., 2014). Some students even question the assessability of such projects altogether, pointing to a gap regarding how to make CE more graspable for teachers and learners, which was identified in previous, CE-related research (Göbl, Guenther, et al., 2023; Kaspersen et al., 2021).

Students often build assessment on accompanying tasks rather than designed prototypes

Students consider a number of different outputs and data for their evaluation, including the designed artefacts for their projects. However, many students feel additional tasks and outputs, rather than designed prototypes, to assess project work would be more appropriate for their teaching, including worksheets or presentations. Not all students provide rationale for these decisions, but some reflections indicate that this may also be based on difficulties to assess individual solutions and integrate subject-specific learning goals into prototype construction – an issue which is worth addressing in teacher education. However, while previous works suggest to tightly couple assessment (and its underlying criteria) with the process of building the artefact (Kim et al., 2020), not all valued competencies (see above) may be easily reflected here, e.g. team work (which is suggested to be assessed based on e.g. observations) or problem solving competencies (considered to be visible via documentation, reflections or presentations). In order to address this, previous works translate the constructionist idea of "objects-to-learn-with" in a classroom to the concept of reflective portfolios (Fields et al., 2018). This allows for a broader adaptation of the concept. rather than merely focusing on artefacts resulting from e.g. making, robotics or other creative technology projects. This is also underlined by students' reflections that the quality of the artefact is not that important, connected to the emphasis of learning based on mistakes and a look at the process additionally to the output – much in line with CE's philosophy (Göbl, Guenther, et al., 2023). Interestingly, some students already link specific stages of the CE process model to specific methods and outputs, for example presentations in order to provide room to reflect on (stage 5 of the CE process model) and argue (stages 6) the design process.

5.1 Limitation

Students from different subject-backgrounds took part in the seminar, bringing different viewpoints and experiences into the group. Additionally, the course is based on students' experiences with CE in higher education, which does not fully reflect challenges inherent to primary or secondary education. Finally, the course setup and assessment designed by the course instructor (i.e., the author of this paper) may impact students' considerations of assessment methods by serving as familiar examples.

6. Conclusion

Computational Empowerment integrates and expands on constructionist ideas to foster digital literacy. Its inherent goals are well in line with current challenges in educational research and practice, yet, there are many remaining issues in aligning its approach with formal educational policy and practice. The presented work provides insights into students' perspectives on assessing CE-based work. This can help to pinpoint knowledge gaps and insecurities of prospective teachers and other barriers in order to better implement CE in teacher education. The paper zooms in on two previously identified barriers: assessment of CE-related learning and consideration of how to integrate CE into teacher education. This paper finds that students value a broad range of subject-specific and cross-curricular competencies and implement a range of methods to assess them next to artefact construction. However, results also suggest that CE and related concepts may need more explicit integration into teacher education for successful implementation and there is a need for more exposure to CE's critical and sustainable dimensions.

Further steps are necessary to bridge the gap between CE and formal education, including explicit integration of CE into teacher education curricula and the investigation of corresponding measurement methods. Additionally, further implementation of CE-based projects in accordance with restrictions and requirements posed by formal educational settings should be explored and translated into further measures.

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