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Operationalizing education 4.0: a structured method for course materials and assessment alignment

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The rapid evolution of labor market demands, driven by technological and societal transformations, has intensified the need for higher education to foster future-oriented competencies. Frameworks such as Education 4.0 emphasize the development of abilities, skills, attitudes, and values; such as problem-solving, critical thinking, adaptability, and curiosity; alongside disciplinary knowledge. However, translating these competencies into course-level practice remains a challenge for educators, especially with regard to course materials and assessment methods. This study addresses this gap by proposing and evaluating a structured, instructor-led method for course redesign aligned with the Education 4.0 framework (E4CAM). Through an iterative research process involving literature reviews, expert workshops, and in-depth interviews, E4CAM integrates self-assessment checklists and targeted action guidelines to support competency integration. E4CAM was evaluated through two workshops and experimental applications involving university instructors. Results indicate E4CAM's practical relevance and adaptability across course levels and disciplines. By enabling instructors to systematically align course content and assessments with Education 4.0 competencies, the proposed approach offers a scalable tool for enhancing pedagogical practices and advancing competency-based education in higher education.

KEYWORDS

Education 4.0, course redesign, problem-solving, critical thinking, curiosity, adaptability

1 Introduction

The landscape of higher education is undergoing a fundamental transformation in response to global technological, economic, and societal shifts. The accelerating pace of the Fourth Industrial Revolution, characterized by automation, digitalization, and complex problem environments, has amplified the need for future-ready graduates equipped not only with disciplinary knowledge but also with transversal competencies (Raitskaya and Tikhonova, 2019). These include cognitive skills such as critical thinking (Utami et al., 2019) and problem-solving (Frey et al., 2022), as well as personal and social attributes like adaptability and curiosity. Global initiatives, such as the World Economic Forum's Education 4.0 framework, emphasize a reorientation of education systems toward these holistic learning outcomes (World Economic Forum, 2023).

However, despite growing international consensus around the importance of such competencies, their translation into teaching practices remains limited (Grebe, 2023; Raitskaya and Tikhonova, 2019). Most efforts at competency development in higher education remain at the policy or program level, while the implementation at the level of

individual courses; particularly in the design of course materials and assessment methods; often lacks systematic support (Nieminen, 2024). The World Economic Forum estimates that investing in one core skill, collaborative problem-solving, could add as much as \$2.54 trillion to global GDP (World Economic Forum, 2023), yet UNICEF reports that less than half of young people worldwide are on track to acquire the full range of skills needed for success in work and life (Alejo and Yao, 2022). Recent studies highlight a gap between the desired learning outcomes outlined in policy frameworks and the pedagogical tools available to instructors to achieve them in practice (Alejo and Yao, 2022; Bhuttah et al., 2024). This disconnect underscores the need for evidence-based, operational methods that enable educators to embed Education 4.0 competencies into both the content and evaluation mechanisms of their courses.

Hence, this study aims to develop and evaluate a structured method for systematically redesigning course materials and assessment strategies in higher education to align with key competencies promoted by the Education 4.0 framework. This research is guided by the following research question: How should course materials and assessment methods be designed to effectively support the integration of Education 4.0 competencies?

This research responds to this challenge by introducing a structured, instructor-led method for redesigning course materials and assessment strategies. The method supports alignment with the Education 4.0 framework by targeting four key competencies: problem-solving, critical thinking, adaptability, and curiosity. Through an iterative research process involving literature reviews, expert workshops, and in-depth interviews, the method incorporates diagnostic self-assessment tools and corresponding action guidelines. These instruments provide practical, scalable means for instructors to evaluate the extent to which their courses reflect future-oriented competencies and to implement targeted improvements.

The remainder of this article unfolds as follows. Section 2 introduces the Education 4.0 framework, which provides the theoretical foundation for this study. Section 3 outlines the research design, followed by a review of related work in Section 4. Section 5 then presents the proposed course redesign method (E4CAM), while Section 6 reports on its evaluation through workshops and experimentation. Section 7 discusses the findings and their pedagogical implications. Finally, Section 8 concludes the paper by reflecting on the contributions, acknowledging limitations, and suggesting directions for future research.

2 Education 4.0 framework

Education 4.0 signifies a fundamental transformation in educational philosophy, driven by the imperative to equip learners with the competencies required to navigate an increasingly dynamic and technology-driven world (Grebe, 2023). Anchored in the initiatives of the World Economic Forum, this framework advocates for a holistic development model that prioritizes not only knowledge acquisition but also the cultivation of abilities, skills, attitudes, and values. Unlike traditional education paradigms that emphasize content memorization, Education 4.0 shifts the focus toward future-oriented competencies designed to foster

adaptability, critical thinking, and lifelong learning (Liwanag and Lunar, 2023).

The Education 4.0 system is structured with a set of characteristics that are arranged like a tree. The tree has three levels: Level 1 consists of basic characteristics, Level 2 consists of more specific characteristics, and Level 3 consists of emphasized characteristics. See Figure 1 for a visual representation. In summary, the Education 4.0 setup has a clear hierarchy of characteristics that start with basic and become more specific and emphasized as you move up the levels.

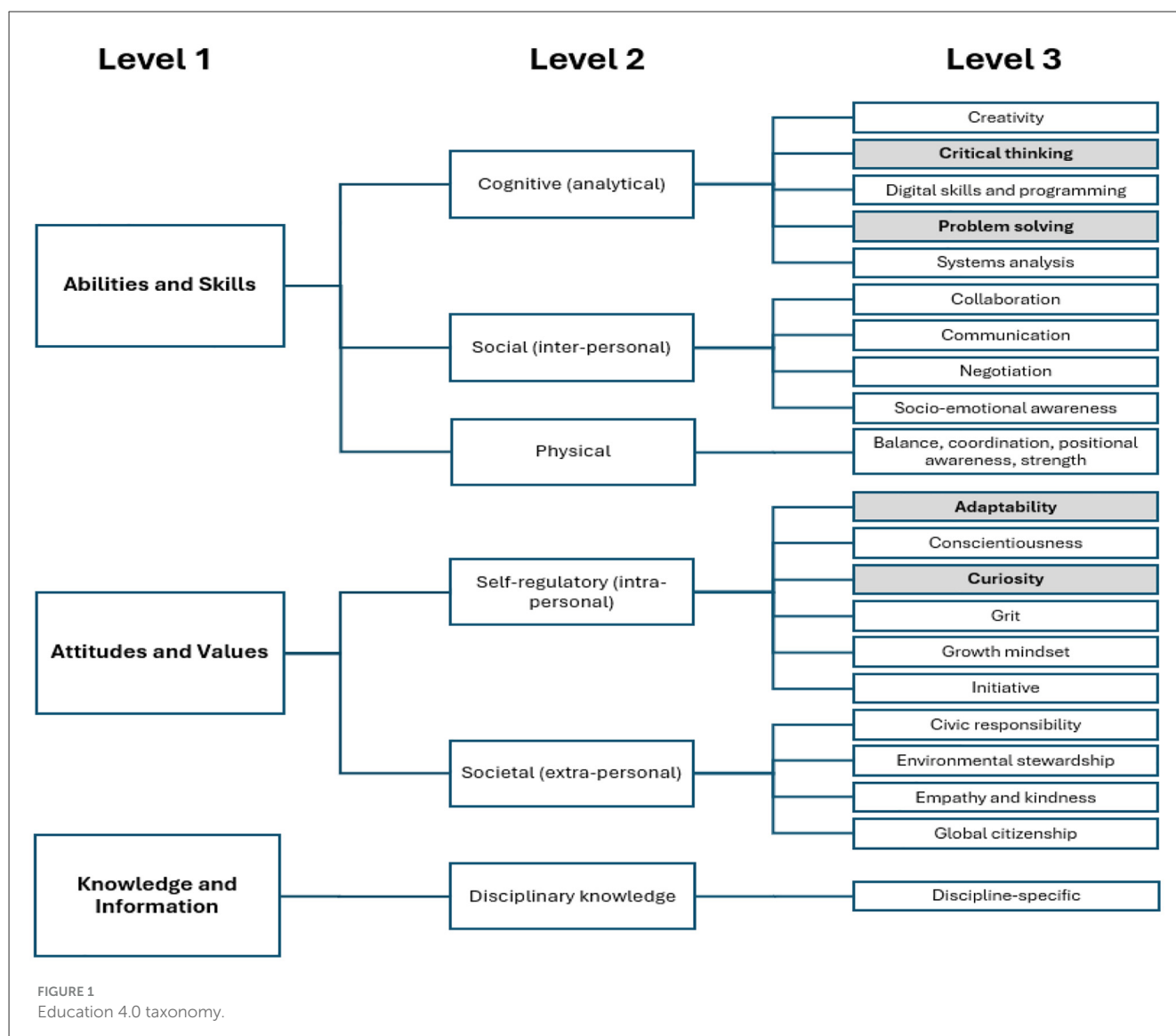
- **Skills and Competencies:** Traditional education focuses more on thinking skills, but employers want people with good personal skills too. Physical skills are part of this.
- **Attitudes and Values:** These are personal qualities important for lifelong learning. They're more about "why" we do things than "how." Education 4.0 splits these into self-regulated personal and social traits.
- **Knowledge and Information:** Schools still teach memorization, but technology changes how we handle information. Education 4.0 doesn't just focus on facts; it looks at other skills too.

The Education 4.0 framework originated as a response to the changing demands of the Fourth Industrial Revolution, emphasizing not only digital literacy and technical proficiency but also human-centered competencies such as creativity, collaboration, adaptability, and ethical awareness. It represents a shift from knowledge transmission toward learner empowerment and competency-based education. In this sense, Education 4.0 integrates cognitive, interpersonal, and intrapersonal domains of learning, aligning educational outcomes with the complex, interdisciplinary challenges of modern work and society. This orientation provides the theoretical foundation for E4CAM, which translates the high-level principles of Education 4.0 into concrete, course-level design and assessment practices. Through this alignment, the study operationalizes an abstract global framework into actionable pedagogical tools for instructors.

In this study, we focus on the "abilities and skills" and the "attitudes and values", owing to the fact that disciplinary knowledge is abundant in many studies (Alejo and Yao, 2022; Habets et al., 2020; Koyunlu Ünlü and Dökme, 2022; Utami et al., 2019).

3 The research design

This study adopted a multi-stage, iterative research design that combined literature reviews, in-depth interviews, workshops, and experimentation sessions to develop and refine the proposed course redesign method (E4CAM). The development process was informed by a comprehensive literature review on competency-based education and course assessment frameworks, followed by in-depth interviews and workshops with instructors to identify practical needs and constraints in aligning courses with the Education 4.0 competencies. These iterative stages ensured that E4CAM was conceptually grounded in theory while remaining directly applicable to teaching practice. The process unfolded



in three main phases: initial development, pilot testing, and subsequent refinement based on feedback.

The work began with a comprehensive review of related literature, which served as the foundation for constructing E4CAM. The resulting framework consists of sixteen structured questionnaires that enable instructors to evaluate both their course materials and assessment practices. These instruments provide diagnostic insights and suggest action points to address identified shortcomings, thereby facilitating alignment with the Education 4.0 framework across targeted abilities, skills, attitudes, and values. E4CAM was then evaluated and iteratively improved through workshops and experimentation, as detailed in Section 5. An overview of the research design is presented in Figure 2.

E4CAM we have designed consists of 16 tables which could be self-administered by an instructor. In order for an instructor to use the proposed method, we first explain the components of the method. All sixteen tables are included in Appendix A and B of this paper.

Table 1 provides an overview of the main components of E4CAM and illustrates how each part of the method connects to the

core dimensions of the Education 4.0 framework. The sixteen tables are grouped into four categories; course material checklists, course assessment checklists, action plans for materials, and action plans for assessment; each addressing the four targeted competencies: problem-solving, critical thinking, adaptability, and curiosity. Together, these components guide instructors in evaluating and improving both the content and assessment elements of their courses in line with Education 4.0 competencies.

The instructor can apply E4CAM method to their courses and take course redesign actions as they unfold. However, the impact of the redesign needs to be further investigated in a longitudinal manner.

4 Related work

4.1 Course assessment and skill transfer frameworks

Several studies have addressed how course design and evaluation can support skill acquisition and transfer from the

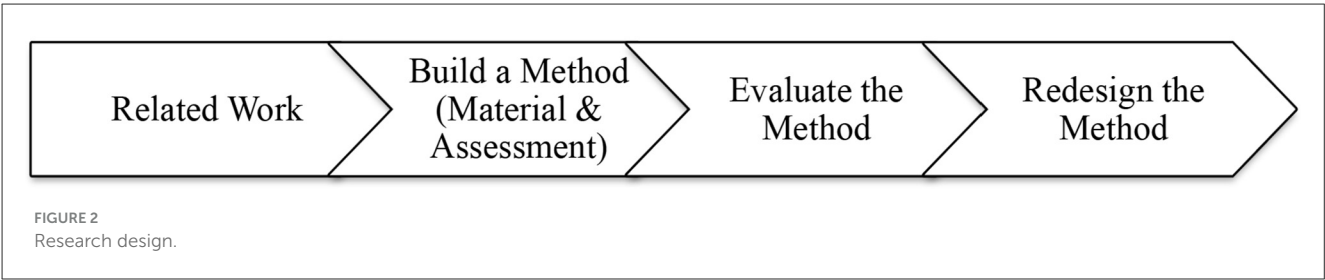


TABLE 1 The components of E4CAM.

Component	Tables	Object	Description
Checklist for the course material	1–4	Table 1	This table includes questions which the instructor needs to answer concerning the problem solving skill and how it is addressed in the course material
		Table 2	This table includes questions which the instructor needs to answer concerning the critical thinking skill and how it is addressed in the course material
		Table 3	This table includes questions which the instructor needs to answer concerning the adaptability as an attitude and how it is addressed in the course material
		Table 4	This table includes questions which the instructor needs to answer concerning the curiosity as an attitude and how it is addressed in the course material
Checklist for the course assessment	5–8	Table 5	This table includes questions which the instructor needs to answer concerning the problem solving skill and how it is addressed in the course assessment
		Table 6	This table includes questions which the instructor needs to answer concerning the critical thinking skill and how it is addressed in the course assessment
		Table 7	This table includes questions which the instructor needs to answer concerning the adaptability as an attitude and how it is addressed in the course assessment
		Table 8	This table includes questions which the instructor needs to answer concerning the curiosity as an attitude and how it is addressed in the course assessment
Actions for the course material	9–12	Table 9	This table includes actions which the instructor pursue concerning the problem solving skill and how it could be addressed in the course material
		Table 10	This table includes actions which the instructor needs to answer concerning the critical thinking skill and how it could be addressed in the course material
		Table 11	This table includes actions which the instructor needs to answer concerning the adaptability as an attitude and how it could be addressed in the course material
		Table 12	This table includes actions which the instructor needs to answer concerning the curiosity as an attitude and how it could be addressed in the course material
Actions for the course assessment	13–16	Table 13	This table includes actions which the instructor needs to answer concerning the problem solving skill and how it could be addressed in the course assessment
		Table 14	This table includes actions which the instructor needs to answer concerning the critical thinking skill and how it could be addressed in the course assessment
		Table 15	This table includes actions which the instructor needs to answer concerning the adaptability as an attitude and how it could be addressed in the course assessment
		Table 16	This table includes actions which the instructor needs to answer concerning the curiosity as an attitude and how it could be addressed in the course assessment

classroom to professional contexts. [Fischer et al. \(2022\)](#) introduced the Course Assessment for Skill Transfer (CAST) framework, which provides a structured process for instructors and evaluators to assess how courses foster essential skills and their transfer to real-world settings. CAST includes four sequential stages: identifying the skills that a course aims to teach, reviewing where and how those skills appear in the course content, assessing student learning outcomes, and checking whether the acquired skills are transferred beyond the course. The framework emphasizes instructor reflection, systematic documentation, and the alignment of course design with workforce-oriented competencies such as problem solving, critical thinking, and adaptability. Other evaluation-oriented models, including [Praslova \(2010\)](#) adaptation of Kirkpatrick's four-level training evaluation model, also highlight the importance of connecting course outcomes with observable performance changes. While these approaches focus primarily on evaluating existing courses, the present study builds on their principles by operationalizing the assessment of competencies within the course redesign process itself. Through its self-assessment checklists and action tables, our method extends this

line of work by enabling instructors not only to evaluate but also to iteratively realign their course materials and assessments with the competencies defined by the Education 4.0 framework.

4.2 Abilities and skills

The Education 4.0 framework emphasizes the significance of abilities and skills in preparing learners for the future workforce. Studies have shown that problem-solving and critical thinking drive economic growth and innovation (Campo et al., 2023; Flores et al., 2020; Goczek et al., 2021). Employers across industries increasingly value these skills, highlighting the need for educational institutions to incorporate them into their curricula, from early childhood education to higher education. The framework also places a significant emphasis on the development of abilities and skills that are essential for navigating the complexities of our contemporary world. These capabilities encompass both cognitive and analytical aptitudes, such as creativity, critical thinking, and problem-solving, as well as interpersonal (non-cognitive) skills, including communication and collaboration. In a rapidly evolving job market, employers increasingly prioritize candidates who possess a diverse set of skills, ranging from technical proficiencies to socio-emotional competencies.

Research indicates a growing demand for skills that transcend traditional disciplinary boundaries (Koyunlu Ünlü and Dökme, 2022). There has been a notable increase in the demand for digital literacy, critical thinking, and creativity in recent years, reflecting the evolving nature of work in the digital era. Despite employers recognizing the importance of interpersonal skills, education systems have historically placed greater emphasis on cognitive and analytical abilities. This imbalance presents a significant challenge, as interpersonal skills are increasingly recognized as essential for success in the workplace. Socio-emotional skills, in particular, have been found to influence academic performance and job preparedness, highlighting the need for a holistic approach to education that integrates cognitive and non-cognitive skills development (Kautz et al., 2014).

4.3 Attitudes and values

In addition to abilities and skills, Education 4.0 places significant emphasis on fostering positive attitudes and values among learners. This includes cultivating a mindset of curiosity, adaptability, resilience, and collaboration. Studies have shown that these socio-emotional competencies are not only predictive of academic and career success but also contribute to the development of well-rounded individuals capable of navigating the complexities of the modern world (Chatard and Selimbegovic, 2007).

Attitudes and values play a crucial role in shaping individuals' behavior, motivation, and engagement with society. Within the Education 4.0 framework, attitudes and values are categorized into intra-personal and extra-personal domains. Intra-personal qualities encompass personal motivation, curiosity, confidence, resilience, and grit, which are essential for fostering a growth mindset and overcoming challenges. Extra-personal societal aptitudes include

cultural competence, civic responsibility, and environmental stewardship, which contribute to the development of cohesive communities and sustainable societies.

The cultivation of attitudes and values is not only integral to individual wellbeing but also essential for promoting social cohesion in an increasingly globalized world. Education philosophers have long recognized the importance of instilling moral and ethical principles in the curriculum to guide individuals' actions and decision-making. As technological advancements continue to shape society, there is a growing need for ethical guidance to ensure that individuals are treated fairly, and their rights and freedoms are protected in the face of emerging technologies such as gene editing, artificial intelligence, and data surveillance systems (Espinoza Cruz et al., 2021).

4.4 Overview of the emphasized elements

Within the realm of abilities and skills, as well as attitudes and values, Education 4.0 specifically prioritizes certain competencies deemed essential for thriving in the Fourth Industrial Revolution. Problem-solving and critical thinking emerge as cornerstones of this framework, reflecting the need for individuals to analyze complex problems, generate innovative solutions, and adapt to changing circumstances (Garcia et al., 2020; Rivas et al., 2022). Moreover, curiosity and adaptability are identified as key values that underpin lifelong learning and personal growth, enabling individuals to explore new ideas, perspectives, and technologies with an open mind (Lee et al., 2022). Accordingly, the core focus of this project will be on these four aspects, which belong to the two categories above. These aspects are problem-solving, critical thinking, curiosity, and adaptability.

4.4.1 Problem-solving

Problem-solving skills are fundamental competencies for success in higher education and the modern workforce. These skills enable students to identify, analyze, and resolve complex issues effectively (Garcia et al., 2020; Rivas et al., 2022). In higher education, problem-solving is often integrated into curricula through activities such as case studies, simulations, and project-based learning. Research indicates employers prioritize candidates who demonstrate strong problem-solving abilities, as evidenced by job postings that frequently list problem-solving as a key requirement. By emphasizing problem-solving in higher education, institutions prepare students to tackle real-world challenges and adapt to evolving professional landscapes (Habets et al., 2020). This means that students should receive training in problem-solving that is specific to their field of work.

4.4.2 Critical thinking

Critical thinking skills are essential for higher education students to evaluate information critically, analyze arguments, and make informed decisions (Utami et al., 2019). Higher education institutions are increasingly incorporating critical thinking into their curricula through activities such as debates, critical reading assignments, and research projects. Employers value critical

thinking skills as they enable employees to approach problems with analytical rigor and creativity. By fostering critical thinking in higher education, institutions empower students to become independent learners and adaptable problem-solvers in diverse contexts (Habets et al., 2020).

4.4.3 Curiosity

Curiosity is a foundational value that drives exploration, innovation, and lifelong learning. In higher education, cultivating curiosity involves fostering an environment that encourages questioning, exploration, and intellectual curiosity (Lee et al., 2022). Curiosity-driven learning experiences, such as research projects, seminars, and interdisciplinary courses, provide students with opportunities to pursue their interests and develop a passion for learning (Cain, 2019). Employers value curious employees who demonstrate a thirst for knowledge and a willingness to explore new ideas and approaches (Bower and Konwerski, 2017). Higher education institutions inspire a lifelong passion for learning, nurturing curiosity and a can-do spirit that empowers students to take on any challenge.

4.4.4 Adaptability

Adaptability is a critical value that enables individuals to thrive in dynamic and uncertain environments. In higher education, nurturing adaptability involves providing students with opportunities to develop resilience, flexibility, and the ability to learn from experiences (Ebenehi et al., 2016; Stockinger et al., 2021). Experiential learning, internships, and study abroad programs are examples of initiatives that promote adaptability by exposing students to diverse cultures, perspectives, and challenges. Employers seek adaptable employees who can navigate change, respond to adversity, and innovate in rapidly evolving industries. By fostering adaptability in higher education, institutions equip students with the skills and mindset needed to succeed in an ever-changing world (Stockinger et al., 2021).

5 The proposed education 4.0 course alignment method (E4CAM)

Building on the research design described in Section 3, this section presents the detailed structure of E4CAM, which operationalizes the Education 4.0 framework through a set of self-assessment and action-planning instruments. E4CAM consists of two main sets of tables. The first set includes a checklist for each of the previously mentioned elements, addressing both course materials and course assessments. It is worth noting that by materials, we mean course literature, lectures, workshops, case studies, and any other means of input for students to work with during the course. Assessment could include a final examination, lab project, group project, quizzes, and any other means used to assess learning outcomes. For this, eight tables were developed based on a literature review, highlighting important considerations. These tables serve as a self-assessment tool for educators to evaluate how well their courses align with the Education 4.0 framework, with a particular emphasis on the four chosen key elements. [Appendix A](#)

contains these eight tables, which function as checklists for this purpose. Each checklist table focuses on one of the four Education 4.0 competencies; problem-solving, critical thinking, adaptability, and curiosity; and allows instructors to identify how strongly each is reflected in their course materials and assessments. For example, the problem-solving checklist prompts instructors to consider whether their course engages students in real-world problem contexts and collaborative inquiry. The corresponding action tables ([Appendix B](#)) then provide targeted suggestions for course redesign based on the diagnostic results. The answers to each checklist item are binary (yes or no), meaning no further explanations are required for the responses.

After that, the actions for each of the abovementioned items in relation to both course materials and course assessment. E4CAM defines action points for each component listed, such as problem-solving in materials or critical thinking in assessment, based on the results of the corresponding checklist. It begins by categorizing the assessment level as “highly emphasized elements” “moderate emphasized elements” or “low emphasized elements” based on the “Yes” responses in the checklist. If more than three-quarters of the answers is “Yes,” the assessment is classified as “highly emphasized elements”; between half and three quarters, it is classified as “moderate emphasized elements,”; and below half, it is classified as “low emphasized elements.”

For “highly emphasized elements” courses, where more than three-quarters of the checklist items are affirmative, no immediate action is necessary as the alignment with the Education 4.0 framework seems satisfactory.

In the case of “moderate emphasized elements” courses, indicating that responses are between half and three-quarters, E4CAM prescribes specific actions to improve alignment. These actions could include revising course materials or assessment strategies to address the deficiencies identified in the checklist.

For the “low emphasized elements” courses, where less than half of the checklist items are confirmed, E4CAM recommends more relevant actions to address the gaps more comprehensively. These added actions might involve significantly restructuring course materials or assessments to better incorporate the targeted skills or values.

The specific actions to be taken at each level can vary depending on the identified shortcomings in the checklist analysis. These actions could range from updating content materials to incorporating new instructional strategies or providing additional training for educators to enhance their ability to foster the targeted skills or values in students. [Appendix B](#) shows the developed tables for actions to be taken into account, as explained.

6 Evaluation and application of E4CAM

This section first describes how the evaluation and application of E4CAM were conducted and then summarizes the key insights obtained from these activities. In order to evaluate and experiment with E4CAM, we conducted one workshop to first evaluate and refine E4CAM and then an extensive in-depth discussion session with two-course teachers, each taking three hours to experiment with E4CAM. These steps were essential for refining

E4CAM and ensuring its practical applicability in real-world educational settings.

6.1 Evaluation workshop

In the first workshop, held with eight university instructors from the Information Systems research group at Luleå University of Technology, we focused on evaluating the method's structure, clarity, and relevance. Information Systems research group refers to the academic field encompassing four educational programs at the university: Data Science and Information Security at the master's level, and System Science and Digital Service Innovation at the bachelor's level. The participating instructors represented these programs and contributed perspectives based on their experience in teaching and curriculum development within these domains.

Participants reviewed the checklist, which assesses course alignment with core competencies namely, problem-solving, critical thinking, adaptability, and curiosity. We asked them to provide input on the checklist's clarity, the potential bias in the questions, and the relevance of the categories to their teaching experiences.

The feedback led to several key improvements:

- **Simplification of Action Tables:** The action tables were revised by removing the tiered levels of course maturity, making them more flexible. Instead of being constrained by levels, we introduced a "relevant/irrelevant" column to allow instructors to select actions that best fit their course context.
- **Customization for Programs and Courses:** The instructors suggested that the questions now are related to both the course and program levels. As a result, we restructured some of the checklists and questions to ensure they could be clearly related to the course level at this stage.
- **General Feedback:** General feedback on the clarity of the questions, overall structure, and the presentation of E4CAM was also incorporated to make the tool more user-friendly.

The participating instructors represented diverse backgrounds within the Information Systems discipline, with teaching experience ranging from 2 to over 30 years. Several participants had prior involvement in curriculum development or educational innovation projects. Feedback was collected through group discussions, written notes, and post-session reflections. A qualitative content review was conducted to synthesize key themes emerging from participants' comments, focusing on the perceived clarity, applicability, and scalability of E4CAM. As one participant noted, "The method helped me realize which competencies are addressed only implicitly in my course and where adjustments could make them more visible to students." Another reflected, "It provides a concrete structure for something we often do intuitively but not systematically." These insights were instrumental in refining the checklists and simplifying the action tables.

6.2 Application workshop

To apply and test E4CAM in practice and examine its applicability, we organized two follow-up sessions, in form of

in-depth interviews, each lasting 3 h, with instructors from two programs: one from a bachelor's program and one from a master's program. These sessions aimed to apply E4CAM and evaluate its practical usefulness by having the instructors use the checklist and action plans to evaluate their courses.

During these workshops, the instructors worked through E4CAM step by step, providing detailed reflections on the relevance and practicality of each question. E4CAM was well-received overall, with both instructors finding it a valuable self-assessment tool for evaluating how well their course materials aligned with the Education 4.0 framework.

Key outcomes from these experimentation sessions included:

- **Revisions of Course-Specific Questions:** Several questions were revised to better reflect the realities of different educational levels (e.g., bachelor's vs. master's). Some questions that were initially too broad or abstract were refined to be more actionable at the course level.
- **Applicability at Different Academic Levels:** The feedback highlighted that certain questions were more applicable at the program level, while others fit better within individual course contexts. We adapted E4CAM to be clearer and more to the point.
- **The workshops also served as an opportunity to validate the practicality of E4CAM and ensure that the questions and action plans were grounded in real teaching practices.** The feedback gathered during these sessions was instrumental in refining the final version of E4CAM, ensuring it is both comprehensive and adaptable.

Instructors for the experimentation sessions were selected through purposive sampling based on their interest in course innovation and previous collaboration with the research team. One instructor was from a bachelor's-level program in Information Systems, and the other from a master's-level program in Data Science. Both had more than 10 years of university teaching experience. Each session lasted approximately 3 h and included reflective dialogue and hands-on testing of E4CAM tables. Feedback was transcribed and analyzed using open coding to identify recurring themes, such as clarity of instructions, perceived relevance, and ease of adaptation. The analysis emphasized instructor reflections as interpretive data, consistent with qualitative workshop evaluation methods in educational research.

7 Discussion

Several key insights emerged throughout the development and implementation of this method for aligning courses with the Education 4.0 framework. A central lesson was the significance of flexibility and adaptability in educational design. The Education 4.0 framework emphasizes competencies like problem-solving, critical thinking, adaptability, and curiosity. However, during the workshops, it became clear that the practical application of these competencies varies widely across disciplines and educational levels, as also highlighted by the previous research (Falcus et al., 2019; Frey et al., 2022). This reinforced the importance of designing tools that allow instructors to customize the framework to their

specific teaching contexts, ensuring that courses are responsive to the diverse needs of students.

From a pedagogical standpoint, active instructor involvement proved essential for providing constructive input. The workshops revealed that instructors often face challenges translating high-level educational frameworks into actionable course design. The collaborative evaluation process highlighted the need for pedagogical tools that are conceptually sound, practical, and easy to implement. Instructors valued the simplified checklist and action plans because they offered a straightforward, step-by-step approach to integrating Education 4.0 principles without overwhelming them with abstract theory. This underscores the need for user-friendly, adaptable tools in pedagogical innovations.

Furthermore, instructor feedback validated the student-centered focus of the Education 4.0 framework, emphasizing skills that prepare learners for a dynamic and uncertain future. The workshops confirmed that educators recognize the importance of fostering lifelong learning competencies in their students. However, applying these competencies in the classroom requires intentional, carefully designed materials and assessments. This insight led to the revision of E4CAM to ensure that it supports contemporary labor market needs and encourages students to engage in critical reflection and self-directed learning actively.

The proposed method for course redesign provides an adaptable framework that aligns with the competencies of the Education 4.0 framework. Through the integration of problem-solving, critical thinking, curiosity, and adaptability into both course material and assessment, E4CAM moves beyond traditional models that purely focus on knowledge and information. This focus fosters a more holistic approach to student development, preparing graduates for a dynamic and ever-evolving labor market. Instructors reported that using this structured method not only clarified areas of improvement in course design but also facilitated reflective teaching practices. By embedding these critical skills and values into the curriculum, educators can promote self-directed, lifelong learning among students, addressing a vital gap in current education systems.

A key contribution of this study is that it operationalizes the abstract principles of Education 4.0 into a concrete, instructor-oriented method. While the literature has long emphasized the importance of transversal competencies, many frameworks remain at the policy or institutional level, lacking actionable guidance for individual educators (Grebe, 2023; Nieminen, 2024). By offering a structured set of self-assessment checklists and action tables, this study addresses the “last-mile” challenge in educational reform; how theoretical taxonomies can be translated into daily teaching practices. This makes the method particularly relevant in higher education systems where instructors often experience autonomy in course design but limited institutional scaffolding for integrating new pedagogical models. In this sense, the proposed approach not only bridges the gap between high-level frameworks and classroom practice but also empowers educators to act as agents of educational change.

The findings also underscore the pedagogical value of reflection and adaptability in course design. The iterative use of self-assessment instruments encouraged instructors to critically evaluate their teaching materials and assessment strategies, which

in turn fostered more intentional alignment with competencies such as critical thinking, problem-solving, adaptability, and curiosity. This aligns with previous research showing that reflective practice among educators is a powerful driver of innovation in teaching and learning (Falcus et al., 2019; Kautz et al., 2014). From a research perspective, the study highlights the need for longitudinal investigations into the sustained impact of course redesign on student outcomes. While the workshops demonstrated E4CAM’s immediate utility, future studies should examine how systematically redesigned courses influence learners’ acquisition of Education 4.0 competencies over time and across diverse disciplinary contexts.

Beyond the course level, the proposed method carries implications for policy and institutional practices in higher education. Accreditation bodies and policy frameworks increasingly demand evidence of competence-based curricula, yet institutions often struggle to demonstrate systematic integration of transversal skills at scale (Bhuttah et al., 2024; Raitskaya and Tikhonova, 2019). E4CAM developed in this study offers a scalable mechanism that could be adopted not only by individual instructors but also by program directors and curriculum committees to evaluate and enhance coherence across courses. Embedding E4CAM into institutional quality assurance processes would provide a structured approach to aligning teaching and assessment practices with Education 4.0 competencies. This integration could support universities in meeting external accountability requirements, while simultaneously ensuring that graduates are equipped with the cognitive, socio-emotional, and adaptive skills required by rapidly evolving labor markets.

7.1 Contributions

This study makes several contributions to both research and practice in higher education. First, it operationalizes the abstract principles of the Education 4.0 framework into a concrete, instructor-oriented method that can be applied at the course level. Through E4CAM, educators are provided with a structured yet flexible tool that translates broad competency frameworks into actionable design and assessment practices. Second, E4CAM contributes to methodological advancement by offering a replicable approach that integrates self-assessment and action planning within the course redesign process. Third, the study contributes empirically by demonstrating, through instructor workshops, how such a tool can support reflective teaching and continuous improvement of course alignment with Education 4.0 competencies. Finally, this work contributes to the broader discourse on competency-based education by highlighting the importance of instructor agency and practical instruments in bridging the gap between policy frameworks and pedagogical implementation.

8 Conclusion

The evaluation and application workshops demonstrated that E4CAM is both practical and adaptable for course redesign across

different educational levels. Instructors found the method helpful in identifying gaps between intended and actual competency integration, particularly regarding problem-solving and critical thinking. Feedback also emphasized the value of E4CAM's structured format, which facilitated reflective teaching and guided targeted improvements in course design. The iterative refinement process resulted in clearer, more flexible action tables and checklists that instructors considered relevant and easy to apply in their contexts.

This study contributes to the ongoing transformation of higher education by operationalizing the Education 4.0 framework at the course level. The findings underscore the importance of systematically cultivating problem-solving and critical thinking skills (Frey et al., 2022; Utami et al., 2019), alongside fostering adaptability and curiosity (Ebenehi et al., 2016; Lee et al., 2022). Together, these competencies enable students not only to thrive in dynamic labor markets but also to develop the resilience and openness required for lifelong learning and meaningful societal contribution.

The proposed course redesign method addresses a key gap in the literature and practice: the lack of practical tools to translate high-level educational frameworks into actionable course design strategies. By combining self-assessment checklists with targeted action plans, E4CAM empowers instructors to critically evaluate and adapt their course materials and assessment methods. The iterative development process, involving literature review, workshops, and experimentation with instructors, ensured both conceptual rigor and practical usability. As such, E4CAM offers a replicable approach that can support educators across disciplines in embedding Education 4.0 competencies into their teaching practices.

Despite these contributions, several limitations should be acknowledged. First, the focus of the study was on individual courses rather than entire programs, which constrains the ability to assess long-term and program-wide impacts. Second, E4CAM was primarily tested as a tool for instructor self-assessment, whereas incorporating student perspectives would enrich its comprehensiveness. Finally, the study focused on four emphasized competencies; problem-solving, critical thinking, adaptability, and curiosity; while other competencies, such as creativity, communication, or grit, remain unexplored.

Future research should therefore expand the scope in several directions. Longitudinal studies could investigate how redesigned courses influence student outcomes over time and across diverse contexts. Comparative analyses could explore the integration of additional competencies identified in the Education 4.0 taxonomy (World Economic Forum, 2023) and in related frameworks (Habets et al., 2020; Koyunlu Ünlü and Dökme, 2022). Moreover, embedding the proposed method into program-level quality assurance processes would strengthen institutional alignment with competence-based education. By extending the approach in these ways, higher education can move beyond knowledge transmission toward equipping learners with the skills, attitudes, and values necessary to navigate the uncertainties of the Fourth Industrial Revolution.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the studies involving humans because the interview and workshop were conducted within our department with colleagues. During both the seminar and the open discussion, participants were informed that the conversations would be used in part for method development, while they also completed the provided templates. The activity primarily involved participants reviewing and validating our checklist. Importantly, all of those we talked to them explicitly agreed and provided their consent. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

AE: Writing – original draft, Writing – review & editing, Methodology, Supervision. AH: Writing – original draft, Writing – review & editing, Formal analysis, Validation.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2025.1694545/full#supplementary-material>

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