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Fostering Teacher Agency Through Participatory Professional Development in Lebanon: An Action Research Study Integrating Coding, Making, and Peer Assessment

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Abstract

In the face of educational disruptions in Lebanon, this action-oriented research explores how a participatory professional development (PD) carefully designed around knowledge-building pedagogy can foster educator agency and ignite system wide pedagogical innovation. The study examines the engagement of 10 teachers as part of the Coding, Making and Research Initiative (CAMRI) engaging 50 public schools. The professional development integrated knowledge building pedagogy in coding (Coder-Maker), peer assessment (peer Scholar) and STEAM+H learning. Using a systems thinking lens and guided by self-determination and diffusion of innovation theories, the research employed a mixed-methods approach to document shifts in teacher confidence, student motivation, and instructional practice. Teachers participated voluntarily, reflecting a strong commitment to transformation despite contextual adversity. This paper presents actionable insights for policymakers and educators aiming to embed innovation into entrenched systems through participatory professional learning.

Summary

This action-oriented design-based research examines the integration of innovative practices in the Lebanese educational system as part of the CAMRI - Coding and Making Research Initiative - focusing on the synergistic implementation of two complementary approaches: Coder-Maker and peerScholar. It examined how, and to what extent, the acquisition of transferable skills imparted through a peerScholar- augmented version of the Coder-Maker program enhanced teacher and learner agency.

CAMRI is managed by the Centre for Educational Research and Development (CERD) and is implemented in close collaboration with the International Education Association (IEA). In this study we report on the engagement of 10 Intermediate and Secondary teachers, their perception of their sense of agency and self-efficacy, students' perceptions because of teachers' engagement in the experience and discuss the extent to which innovation can be integrated into the Lebanese educational system

The action-oriented research draws on system thinking (Burns, 2007), self-determination theory (Ryan & Deci, 2017) and Rogers (1962) diffusion of innovation theories. It utilized mixed methods, combining Coder-Maker course results with post - coding, making and peer-assessment - and post-experience intrinsic motivation questionnaires for teachers and students alongside qualitative data. Qualitative data included post-

experience interviews and participants' participatory engagement in the overall experience.

The peerScholar research was supported by a MITACS award and was conducted under the supervision of Professor Steve Joordens, professor at the University of Toronto, Scarborough. In this report, we highlight key findings from the collected data and offer actionable recommendations for embedding innovation more deeply in Lebanon and more widely within educational systems.

Context

The research took place in Lebanon at a time of immense strain due to the compounded socio-political and economic crises that have gripped the country since 2019. These crises have severely impacted the education sector, with more than 50% of the population living below the poverty line since 2020 (UNICEF, 2020)[1]. The challenges were exacerbated by significant talent drain, declining social cohesion, political instability, a troubling increase in child labor and the recent devastating war resulting in more than 1 million Lebanese displaced in their own country (United Nations News[2])

Despite these challenges, with support from the World Bank, Lebanon continued to pursue its curriculum reform. Part of this effort included piloting CAMRI, under which MITACS awarded the peerScholar augmented version of Coder-Maker research, with the aim to extract valuable lessons and offer recommendations.

CAMRI was proposed to 50, 25 Primary and 25 Secondary Lebanese public-school teachers. Out of the 25 Secondary teachers, 10 joined the professional development program, piloted Coder-Maker and 7 completed the augmented peerScholar experience. We therefore examine the combined impact of these two complementary educational approaches on those teachers and their students. Their experience was totally voluntary, with no obligations, and all teachers could pull-out of the experience and research at any time.

Overview

The CAMRI activities were planned around the academic year to extract lessons learnt from teachers' learning and classroom implementation. The project encountered numerous challenges, including war, school closure and bombs particularly in the South of Lebanon, strikes and delays necessitating a sequential, administrative process that required ongoing approvals at each stage. This disrupted the project's alignment with the academic year and affected participants' sense of continuity, retention rates, and the process of data collection and analysis. However, the shared struggles fostered a strong sense of community among those who completed the experience. The teachers who engaged their students and persevered demonstrated remarkable agency and resilience, driven by the motivating synergy of peerScholar and Coder-Maker and the unwavering support from IEA's trainers and facilitators.

The challenges were multifaceted, including administrative delays, a shortage of technological resources, lack of security, financial, and social stability. Teachers' strikes and administrative delays directly affected teacher engagement, leading to dropouts after attending the introductory orientation day. Teachers' frustrations were compounded by delays in transportation reimbursements for workshops, the need for additional approval letters for classroom implementation, and the slow distribution of resources to schools with outdated computer equipment. Despite these hurdles, strong support from school leadership helped

sustain momentum, allowing in some cases, work to proceed in parallel with administrative approvals. Each challenge highlighted the importance of maintaining strong communication channels among stakeholders, teachers, students and school leadership. IEA's ongoing technical support and transparent communication with teachers provided a detailed understanding of how they progressed, adapted and integrated innovative practices into their classrooms, displaying exceptional flexibility and resilience.

The experience started with a teacher professional development component explained further down in the document before introducing **peerScholar** which is the culmination of extensive research on skill development conducted at the Advanced Learning Technologies Lab at the University of Toronto, under the leadership of Professor Steve Joordens. peerScholar (pS) represents a significant innovation in educational assessment through its use of "Assessment as Learning" (Rodríguez-Gómez & Ibarra-Sáiz, 2015). Unlike traditional assessments, which typically measure the outcomes of a learning experience, Assessment as Learning transforms the assessment process into a learning experience itself (Blythe & Krechevsky, n.d.). peerScholar is conceived to foster the development and acquisition of transferable skills such as critical and creative thinking, effective communication, collaboration, and self-awareness. Additional support for students going through peerScholar is achieved through micro-learning videos. pS provides the necessary structure, support, and timely feedback for transitioning from traditional to innovative educational practices. The process begins with students creating and submitting a draft of their work—such as an essay or research project—on the pS platform. Students then assess the work of their peers, honing their ability to provide constructive feedback. Afterward, they receive feedback on their own draft from their peers, which they use to revise and improve their work before submitting it to their teacher. Throughout this process, students are encouraged to think critically and creatively, learn to give and receive feedback in a socio-emotionally sensitive manner, and navigate the emotional challenges of receiving feedback to focus on the essential information needed for learning and growth.

On the other hand, **Coder-Maker** is a program that teaches individuals computational thinking and the creation of new products through a series of hybrid Knowledge-building (Scardamalia & Bereiter, 2005) courses engaging learners together in using their knowledge in new, complex, and real-life situations. Initiated at the start of the maker movement in education (2014), Coder-Maker is associated with knowledge-building Scardamalia & Bereiter, 2005) pedagogy, constructionism (Papert, 1991) and connectivism (Siemens, 2005), alongside STEAM learning (Schad & Jones, 2020; Halverson & Sheridan, 2014; Martin, 2015; Bevan et al., 2014). Research around the Coder-Maker has shown evidence of depth of impact on teachers and students (Tawileh, 2019) in context of crises by providing learners with pillars of learning - a sense of purpose, technology mediated learning, competences, and connectedness helping individuals to realize their potential as whole individuals (Metni, 2022). The program builds on Learning for Self-Actualization (LSA) framing learning as a holistic and formative process of self-discovery, stipulating that to promote optimal autonomous motivation and intrinsic aspirations, individuals need to engage in meaningful exploration of the self and purposeful actions in the world (Metni, 2025 forthcoming). It provides a coherent meaning-making framework, which addresses the individual's social, emotional, technological and cognitive knowledge-building dimensions through a six-phase Creative Process (CP), Observe, Research, Imagine, Design, Create, and

Review, in which learners progressively learn how to code, use digital technologies, conduct research, apply design thinking and create innovative products. At the end of the process, students create their own innovations referred to as MVPs (minimum valuable products) which they peer reviewed using peerScholar.

Research Questions

Hence, we ask the main research question**:** Does this combination of Coder-Maker and peerScholar have the pedagogical impact we hope it will on teaching and learning with the following sub-questions:

1. What is the interaction between pS and Coder-Maker?
2. What is teachers' perception of their own learning, the experience of working through the process, their motivation, self-efficacy and sense of agency?
3. What is students' perception of the learning experience, how and to what extent are they internally motivated in the process, and their sense of agency?
4. How and to what extent can innovation be diffused into the pedagogical process by early adopters in the education system in Lebanon?

Literature Review

Embracing innovative knowledge-building pedagogy in educational systems is complex and requires considerations beyond mere strategizing around technological implementation i.e., purchasing educational technology, EdTech tools, and training teachers on their use. The optimal innovations in education enable transformative and self-directed learning, nurture learners' agency (Biesta & Tedder, 2006) and equip students with transferable skills critical for active participation in society. Arguably, embedding innovative practices into K-12 classrooms in a durable manner requires nurturing agency and the intrinsic motivation necessary to sustain those skills and practices.

Agency

Research in education reveals that agency is not merely something individuals "have" but rather something they achieve as they navigate, adapt to, and sometimes challenge the educational structures around them (Priestley, 2015). Agency, as the capacity to act meaningfully and independently within one's environment, emerges through a complex interaction between individual abilities and social-material contexts (Priestley, 2015; Pachler et al., 2010). Self-Determination Theory (SDT) illuminates this concept by identifying autonomy, competence, and relatedness as the psychological needs that underpin agency (Deci & Ryan, 2000; Ryan & Deci, 2017). Self-Determination Theory (SDT) explains that people are naturally driven to learn and grow when their fundamental psychological needs are met. These needs include autonomy—the ability to make choices and take ownership of one's actions; competence, the sense of developing skills and being effective in what one does; and relatedness, the feeling of connection and meaningful engagement with others. When these needs are supported, individuals are more likely to be intrinsically motivated, engaged, and willing to take on challenges (Deci & Ryan, 2015).

The Making Movement as Learning

Maker-centered learning is rooted in Papert's (1991) theory of constructionism, which emphasizes learning through making. While often equated with "learning-by-making," Papert clarifies that constructionism extends constructivist principles (Piaget, 1970) by stressing the significance of learners actively constructing public artifacts. This approach challenges traditional instruction by positioning students as active agents in their own learning (Ying, 2018). Clapp et al. (2017) further define maker-centered learning as a process-driven, community-based practice that fosters student agency beyond simply producing artifacts. Although research suggests that maker-centered learning can enhance student engagement, its most profound impact lies in nurturing student autonomy, creativity, and resilience (Clapp et al., 2017). Research further supports the idea that "coding, making, and sharing things is one of the best ways people can learn" (Luckin et al., 2012, p. 25). According to Wing (2006), computational thinking is a fundamental cognitive skill set for problem-solving and a crucial capacity for students to thrive in the digital society. In Coder-Maker, learning through making is maximized by upholding the six knowledge-building tenets: (1) knowledge as a community advancement; (2) knowledge advancement to improve ideas; (3) "knowledge of" in contrast to "knowledge about"; (4) discourse as collaborative problem-solving; (5) constructive use of authoritative information; and (6) understanding as an emergent goal (Scardamalia & Bereiter, 2005). Knowledge-building combined with computational thinking contributes to anchoring transferable skills with a focus on collaboration and authentic problem-solving. It is an approach to learning that engages learners together in using their knowledge in new, complex, and real-life situations.

Hence, the extent to which student agency is fostered in maker-centered learning depends heavily on the pedagogical design, particularly in how knowledge-building principles are embedded. While the ethos of making encourages autonomy and creativity, many implementations risk falling short of these aims. When activities are overly structured or focus primarily on product replication, they limit opportunities for students to engage in collaborative knowledge improvement or to develop deep conceptual understanding. Resnick and Rosenbaum (2013) highlight the difference between structured construction tasks and open-ended tinkering, noting that the latter supports more iterative, student-driven learning. Yet, without deliberate integration of knowledge-building scaffolds, maker activities may fail to support the kind of epistemic agency central to authentic learning (Scardamalia & Bereiter, 2005; Clapp et al., 2017).

Research with teachers reveals that integrating knowledge-building into making practices presents a unique set of challenges. While many educators are enthusiastic about the maker movement, they often struggle to shift from activity-based approaches to designs that promote sustained inquiry, discourse, and collective cognitive responsibility. O'Brien et al. (2016) show that even when teachers embrace making, they may lack frameworks that support deeper learning. Oliver (2016) emphasizes the importance of professional development that moves beyond tool training to help educators rethink their roles, foster idea improvement, and structure classroom communities that support dialogic learning. Teachers need support not only in acquiring maker-related skills, but also in designing learning environments that value students as knowledge creators and nurture their agency through collaborative meaning-making processes.

Assessment as Learning in Maker-Centered Learning

Assessment as learning is a formative approach that positions students as active participants in their own learning processes, fostering metacognition, self-regulation, and transferable skill development (Earl, 2003; Boud, 2000). In contrast to traditional summative assessments, which measure performance against predefined criteria, assessment as learning emphasizes self- and peer-assessment to support deeper understanding and continuous improvement (Andrade & Brookhart, 2020).

The integration of peer assessment within maker-centered learning environments, such as Coder-Maker, enables students to engage in reflective, iterative processes that enhance both their disciplinary knowledge and transferable skills. Research on peerScholar, a digital platform designed for peer assessment, demonstrates its effectiveness and reliability in assessing these skills at scale (Paré & Joordens, 2008). By engaging in iterative feedback cycles, students take ownership of their learning, developing autonomy as they critically evaluate both their own work and that of their peers (Lundberg & Rasmussen, 2018). This formative approach not only reinforces self-directed learning but also strengthens relatedness, as students gain insights into diverse perspectives, fostering empathy and collaborative problem-solving (Nicol, 2020).

Traditional assessments often fail to capture the complexity of transferable skills, focusing primarily on disciplinary knowledge and standardized testing metrics (Gao, Wang, & Kember, 2020). As Joordens, Paré, and Collimore (2014) argue, peer assessment bridges this gap by enabling students to develop critical thinking, metacognitive awareness, and interdisciplinary competencies needed in an increasingly interconnected and innovative world (Dochy, Segers, & Sluijsmans, 1999; Topping, 1998; Liu & Carless, 2006). In the context of Coder-Maker, the use of peer assessment for Minimum Viable Products (MVPs) encourages students to engage collaboratively in reflective practice, enhancing their ability to refine prototypes based on structured, constructive feedback (Sheridan et al., 2014). This process mirrors emergent problem-solving in real-world design and innovation contexts, aligning assessment practices with knowledge-building principles.

Micro-Learning and Student Agency in Assessment

The integration of micro-learning into peerScholar assessment further enhances student engagement. Micro-learning, characterized by short, focused learning segments, aligns with cognitive load theory, which suggests that breaking information into smaller chunks facilitates deeper understanding and application (Sweller, Ayres, & Kalyuga, 2011). Platforms like peerScholar, incorporating micro-learning videos, provide students with targeted instructional support, allowing them to grasp complex concepts incrementally while actively applying their knowledge in real-time assessment cycles. For example, just prior to giving feedback to their peers, students interact with three microlearning videos that explain (1) why giving feedback well is a valuable skill to develop, (2) why giving constructive feedback is so challenging, and (3) six characteristics that define emotionally appropriate constructive feedback.

This approach plays a crucial role in promoting student agency, as learners navigate scaffolded learning experiences that blend assessment with skill development (Zimmerman & Schunk, 2001). Research suggests that formative assessment strategies that integrate technology-enhanced learning environments encourage self-regulation, autonomy, and intrinsic motivation, as students take responsibility for their progress through

structured reflection and peer interactions (Nicol & Macfarlane-Dick, 2006). Moreover, by engaging in authentic, collaborative evaluation processes, students build essential skills for adaptive expertise, preparing them to navigate dynamic and interdisciplinary professional landscapes (Bransford, Brown, & Cocking, 2000). Arguably, the shift toward assessment as learning within maker-centered pedagogies, such as Coder-Maker, represents a paradigm shift in how Lebanese students view assessment and acquire and demonstrate agency.

Theoretical Framework

Combined, Diffusion of Innovation (DOI) theory, Self-Determination Theory (SDT), and Systems Thinking (ST) offer a comprehensive framework for researching and analyzing how pedagogical and technological innovations such as the peerScholar-augmented version of Coder-Maker can be adopted by various teachers and their students before considering how to scale within educational systems. The framework enables examining not only the intrinsic motivation behind adopting new practices, but also the broader structural and relational factors that enable or constrain agency and pedagogical change. Underpinned by SDT elements, autonomy, competence, and relatedness, the Intrinsic Motivation Inventory (IMI) provides a robust methodology and instruments to unpack agency in practice (Deci & Ryan, 2000), which is essential to understand what can drive individuals to be early adopters and venture to try innovative pedagogical approaches. It enables understanding how participating teachers and students perceive the experience of creating and peer-assessing their MVPs. How do they value the experience (autonomy)? Do they feel competent to implement it effectively (self-efficacy)? And do they have a sense of relatedness through their collaborative engagement?

In line with SDT, Diffusion of Innovation (DOI) theory provides a lens for analyzing how the initial motivation of early adopters could be sustained and adopted at scale. The theory suggests that for change to take root, individuals must perceive the innovation as both compatible with existing practices and valuable to their work and lives (Rogers, 2020). In addition, the holistic, non-linearity of Systems Thinking provides the flexibility to analyze the factors that influence early adopters of innovation and allows interconnecting intrinsic motivation factors with causality, which is crucial for identifying leverage points for effective change (Senge, 2006). According to Rogers (2020), early adopters play a crucial role in the spread of new ideas, as they are often influential and can help legitimize an innovation within a social system. Their adoption is based on the value of the innovation and the careful consideration of its benefits. Generally, early adopters tend to have a positive attitude toward change and innovation, are relatively risk-tolerant, socially connected, and optimistic about new practices and technologies.

Hence, combined, SDT, DOI, and ST theories provide a framework to examine the intrinsic motivation factors and relationships that drive or hinder agency of individuals within educational systems, as the factors impacting agency are not isolated events, but part of a larger ecosystem of educational practices and policies

Sample

The teachers who participated were from schools selected by the Ministry of Education and Higher Education (MEHE) to be representative of the various regions in Lebanon, especially those in remote and underserved

locations who generally have low access to innovative learning approaches. The sample was intentionally inclusive of social, economic, geographic, and religious differences, and aimed to enable greater understanding across these differences by bringing teachers and students together with the professional development instructors and MEHE officials. Preference was given to schools where leadership was committed, equipment available and educators of STEAM related subjects were willing to participate. As mentioned in the overview, initially, 50 teachers were invited by the MEHE from 50 pre-selected schools, 25 from Primary and Secondary levels. Schools were chosen based on the availability of a computer lab and the willingness of the school leadership to participate in the research. The selection criteria for teachers emphasized a readiness to learn and implement the program with students, with a preference for those teaching science, computer studies, and mathematics. When schools fitted the criteria, but teachers could not join the TPD, data entry educators were invited to participate.

Out of the 25 teachers, 10 were able to join the Teacher Professional Development (TPD) after the in-person orientation and 7 completed the combined experience. As discussed earlier, circumstances beyond our control, negatively impacted teacher retention rates from the start. Those included mainly safety and lack of stability. The schools in the South were particularly affected by insecurity and frequent school closure due to shelling and ensuring children safety. In addition to instability, the program was impacted by administrative delays and ensuring that resources reached schools. To enrich the data, two teams of students from a semi-private and a private school who had completed the Coder-Maker (CM) experience were invited to participate in the peerScholar (pS) experience.

Teacher Professional Development Experience Overview

The action-oriented design-based research incorporated a knowledge-building and context-sensitive Teacher Professional Development (TPD) experience, meticulously coordinated with officials from the Centre of Educational Research and Development (CERD) at the MEHE who accompanied the teachers' experience. To do this effectively, CERD trainers and the coaches of the Department of Pedagogical Support (DOPS) took the computational thinking courses prior to the teachers and gave qualitative feedback expressing their perspectives about their integration in the education system. This collaboration fostered the formation of a CoP around the Coder-Maker (CM) and peerScholar (pS) programs within the experience. Subsequently CERD officials participated in the peerScholar TPD and day The three phases are described hereafter.

Phase-1: Teachers learnt to code, make, and design learning; In the initial phase of the design-based research, teachers participated in hybrid TPD courses on the IEA Learning online platform. They acquired introductory computational thinking skills in Python, learned how to use the Raspberry Pi, and gained experience programming motors and sensors. Additionally, they engaged in a STEAM+H (Science, Technology, Engineering, Arts, Math, Humanities) course and learned to design projects using the six-phases of the Creative Process-observe, research, imagine, sketch, design, create, and review.

Phase-2: Classroom implementation and project design. In the second phase, teachers applied the newly acquired skills in the classroom. They introduced coding and engaged students using the content from the IEA Learning online platform. Teachers guided their students through introductory Python and circuitry,

leading teams to design projects and create prototypes addressing community issues. Following the 6-phase Creative Process, these projects extended beyond the classroom. Students developed prototypes and produced videos showcasing their MVPs.

Phase-3: Peer assessment day. The experience culminated with students' peer assessing their MVPs during a peer assessment day planned in close collaboration with CERD officials. In preparation of the Peer Assessment Day, the peerScholar pedagogy and platform were introduced to teachers. The Peer Assessment Day took place at the Beirut Digital District (BDD) on June 23, from 9 am to 3 pm with a lunch break at 1 pm. On this day, students, accompanied by their teachers, brought their prototypes and learned how to use peerScholar before participating in a group peer assessment activity.

A total of 27 students, grouped into 9 teams from 7 schools (5 public and 2 private), participated, with one teacher leading two teams. Two CERD officials also took part. The inclusion of the private schools, which had completed the same TPD course, served to enrich the data. During the event, Professor Joordens provided an overview of peerScholar pedagogy and interacted with the teams of students, teachers, and officials. Students were introduced to the pS platform, learning the importance of giving and receiving constructive feedback. In groups, they used pS to assess two other teams' work, discussing their own projects and providing positive and constructive feedback. Following this, they reviewed the feedback received, evaluated it, and reflected on how they might revise their work based on the experience.

Methodology

The research methodology adopted Participatory Action Research (PAR) principles, aligning with the frameworks outlined by Collins et al. (2012) and Cargo and Mercer (2008). It included a strong action-oriented component, engaging CERD trainers, DOPS coaches, Ministry of Education and Higher Education (MEHE) officials, teachers, and students to learn from and reflect on their experiences throughout the process. A CoP was established at the outset, contributing to sustainability, local ownership, and the development of a sense of agency and self-efficacy among participants, key aims of the study. In keeping with PAR's iterative nature, the research design was continuously adapted in collaboration with participants, based on what was feasible within the evolving context and constraints. These tools were developed within the CoP to ensure contextual relevance and to deepen insights into the experiences of both trainers and teachers.

Methods

The study employed a mixed-methods approach, incorporating quantitative and qualitative measures to capture a comprehensive understanding of the experience and data was collected pre-, during-, and post-intervention stages.

Qualitative Measures

Qualitative data was gathered throughout the experience during the TPD community of practice (CoP) regular webinars and through in-depth semi-structured interviews with teachers, students, CERD officials and DOPS coaches. Engagement in the course webinar CoP was ongoing during the TPD courses. During webinars

teachers engaged in conversations about the course, shared their progress while learning and during implementation and expressed the challenges they faced and how they mitigated them. A total of 7 interviews with teachers, and two focus groups were held, one with DOPS coaches and one with CERD trainers. The interviews were analyzed inductively and provided nuanced insights and contextual understanding to support and enrich the quantitative results. The interviews and focus groups were semi-structured and held post implementation. They were held through TEAMS which is the platform used for all the courses' webinars and meetings with teachers. Educators were free to participate, and all meetings were recorded, anonymized, transcribed and analyzed thematically.

Quantitative Measures

Quantitative data collection involved post-unit surveys for the Coder-Maker courses, collected on the IEALearning platform, and pre- and post-experience questionnaires designed to assess the overall experience. Due to administrative delays beyond control, the pre-questionnaires could not be administered. To address this, the post-questionnaires were modified to include a statement that allowed participants to compare participants' engagement in this experience with previous ones. While the planned data collection was disrupted, this did not significantly impact the results, given that the number of participating Secondary teachers dropped from the expected 25 to 10 and out of the 10, 7 teachers completed the coding and making projects with their students and engaged them in peer assessment. So, the smaller sample size was offset by the depth of the qualitative data collected through interviews. Additionally, discussions were held with the Head of Assessment at CERD to get feedback on the peer assessment day and evaluate how peerScholar pedagogy aligns with the curriculum framework objectives.

Courses Unit Feedback

Secondary level teachers completed two coding courses and a STEAM+H pedagogical course on the IEA Learning platform. After each unit, teachers were asked to complete feedback surveys, which included questions about their interest in the units, the clarity of the content, and the competencies gained. The results of these surveys are presented as averages of the 3 courses in the results section.

Experience Pre- and Post-Questionnaires

The experience pre- and post-questionnaires were adapted from the Intrinsic Motivation Inventory (IMI) to reflect the specific context of teaching and learning in this study. The questionnaires consisted of 35 statements for teachers and 20 for students, covering seven subscales. The subscales included: **Interest/Enjoyment** (6 statements for teachers, 3 for students): it is the only subscale that directly measures intrinsic motivation. **Perceived Competence** (6 statements for teachers, 3 for students) is a positive predictor of intrinsic motivation, based on the idea that confidence in their abilities encourages participants to integrate new practices. **Effort/Importance** (4 statements for teachers, 4 for students) assesses the perceived importance of an activity, which correlates with the effort exerted by participants. **Pressure/Tension** (4 statements for teachers, 3 for students) is a negative predictor of intrinsic motivation, with higher pressure correlating with lower motivation

to adopt new practices. **Perceived Choice** (4 statements for teachers, 2 for students) is a positive predictor of intrinsic motivation, based on the notion that voluntary engagement fosters a willingness to try new approaches. **Value/Usefulness** (5 statements for teachers, 2 for students) evaluates how participants internalize the novelty, and its perceived benefits compared to past experiences. **Relatedness** (6 statements for teachers, 3 for students) is about interpersonal interactions, collaboration, and the formation of positive relationships. The post-experience questionnaires were completed by 6 out of the 7 teachers (5 from public schools and 1 from a private school) and 27 students (with numbers split between public and private schools). After completing the questionnaire, participants provided unsolicited feedback on their engagement with Coder-Maker and peerScholar expressing their impressions. All teachers were contacted to ensure that interpretation of the data was correct.

RESULTS

COURSES UNIT FEEDBACK,

The teacher professional development Coder-Maker unit feedback results are summarized in a table (5 being the highest grade) for the computational thinking courses and the STEM pedagogical course.

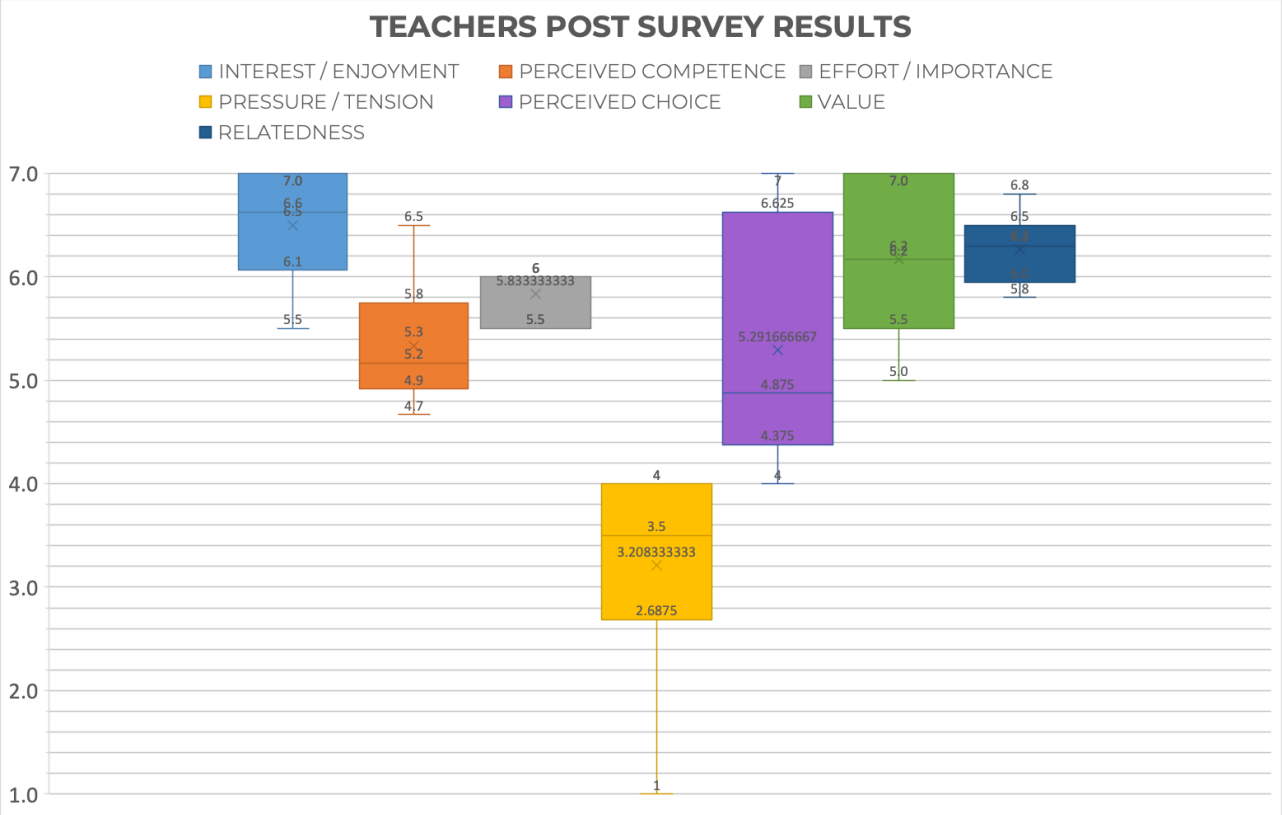
Table 1: *Course Results*

Indicator	Python I	Python II	Pedagogy
Enjoyment	4.18	3.77	3.92
Clarity	4.04	3.32	3.9
Competence	3.93	3.01	3.9

The results show that on average, participants found the Coder-Maker course enjoyable (4.18) and clear (4.04), indicating a positive learning experience. The scores for competence ranged between (3.9 and 4.01) which means that the participants perceived themselves competent. So, the course helped them to deepen their knowledge and gain practical skills. As mentioned earlier, those results were collected on the IEA Learning platform for the modules delivered online.

Teachers Post-Experience Questionnaires Result and Analysis

Figure 1provides teachers' box plots result for the IMI questionnaires following their engagement with peerScholar. **Figure 1***: Teachers' post survey results*



The analysis of teachers' responses to the IMI questionnaires, visualized through box plots across the seven subscales, provides a detailed view of teachers' perception of the experience in the peerScholar enhanced version of Coder-Maker.

Interest and Enjoyment: The box plots reveal that most teachers rated the experience as highly interesting and enjoyable. The interquartile range (IQR) shows that most responses clustered around the upper end of the scale, indicating a strong positive reception for the combined experience with peerScholar. Teachers found the activities engaging, with the median scores reflecting a shared enthusiasm for the content and process.

Perceived Value: Teachers consistently rated the experience as valuable, with the box plots showing a narrow IQR near the higher end of the scale. This suggests that teachers as early adopters not only enjoyed the experience but recognized its significant value for their professional growth and for the benefit of their students. The minimal spread in responses indicates a consensus on the importance of the experience to participants.

Relatedness: The box plots for relatedness indicate a positive shift in the connections between teachers, as well as between teachers and students. The data shows an increased sense of community, with most teachers rating their relationships more positively after the experience. The distribution is skewed towards higher ratings, reflecting the enhanced collaboration and support among participants. Arguably, this can positively impact other teachers to adopt the innovation in the future.

Perceived Tension and Pressure: Interestingly, the box plots show that tension and pressure were perceived as low, with most teachers reporting minimal stress. The IQR is concentrated at the lower end of the

scale, indicating that the experience was conducted in a supportive environment, free from undue pressure. This marks a significant improvement from previous experiences, where higher tension levels were reported.

Competences: Teachers rated their competence as moderate, with the box plots showing a broader IQR. While many teachers felt sufficiently competent to implement the new skills, the data reveals a recognition of the need for further development. The spread of responses suggests that while teachers are confident, there is a desire for additional training to master the skills fully.

Effort: The Effort subscale box plots show that teachers put in a fair amount of effort, with responses clustered around the middle to upper end of the scale. This distribution reflects a balance between effort and perceived value, where teachers were motivated to invest time and energy because they saw the clear benefits of the experience.

Choice: The box plots for choice reveal some variability, indicating that not all teachers felt that participating in the experience was entirely their decision. The wider IQR suggests that some teachers were more compelled than others, possibly due to leadership selection. However, the fact that all participants completed the experience despite this variability underscores the overall value they found in it.

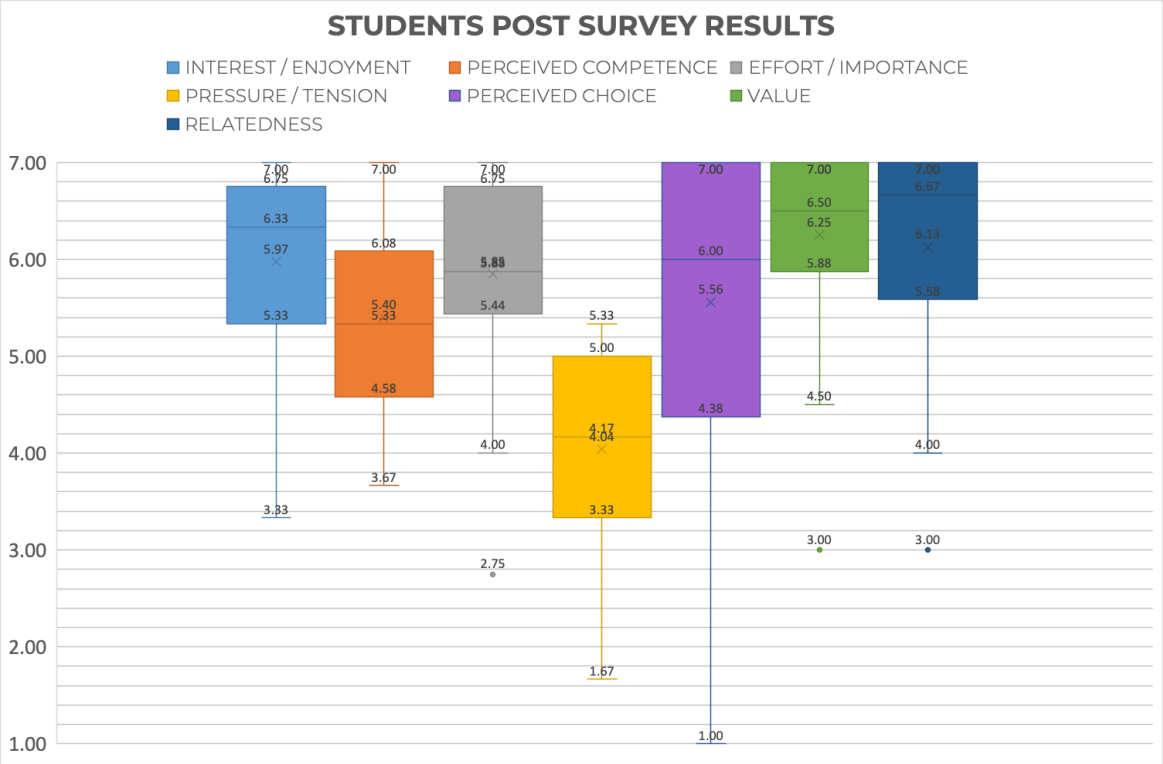
Here are some of the comments added by teachers at the end of the questionnaire: Is there anything else you would like to add?

- I would prefer to have more educational sessions to improve my work.
- The time didn't helped us to do better
- No
- No thanks
- It was a beneficial experience

Students Post-Experience Questionnaire Results and Analysis

Figure 2 presents students' box plots results for the IMI questionnaires with the 7 subscales following their engagement with peerScholar.

Figure 2*: Students' post survey results*



Interest: Overall, students' interest and enjoyment were very high. Indeed, the results show that it was a very enjoyable experience for them, and they were highly interested in it. The interquartile range (IQR) indicates a strong positive reception for the combined experience of Coder-Maker with peerScholar.

Relatedness: The data shows that the experience increased relatedness and they felt more connected to their peers, relating better to them and to their teachers. The large majority appreciated working as a team.

Perceived Tension & Pressure: Overall, students felt more tensed than their teachers and lived the experience with an average amount of pressure. Perhaps the fact that they learnt to use peerScholar in-person and engaged in sharing their MVP and peer assessment the same day contributed to this tension. Interestingly it did not impact their interest, and there was no negative correlation between the enjoyment/interest and the perceived tension.

Competence: Overall, students felt averagely competent through the experience wishing to be more competent. Perhaps because it was their first experience using the platform and engaging in the peer review process.

Importance & Effort: Overall, most students perceived it as a highly valuable experience which was highly important for them, and they put in a fair amount of effort to succeed.

Choice: The box plots indicate that not all students participated by choice. Interestingly, this did not impact their interest as they were all highly interested and recognized the value of the experience, wishing to be more competent at peer assessment. In addition, the fact that all students completed the experience underscores the overall value they found in it. Additionally, the IQR suggests that most students were compelled and found it highly valuable. Here are some of the comments added by students at the end of the questionnaire: Is there anything you would like to add:

- No
- No
- No
- It was a very good experience I enjoyed and had a lot of fun
- Nope
- No
- This event is cool and filled with adventures
- Keep on doing like this projects to encourage the students ● No thanks
- No thank you
- Bo thanks
- I loved this experience
- No
- No thanks this was an incredible experience
- No
- It was a really fun experience and i learned so much from it. Special thanks to whoever helped make it happen.
- Nope
- It was a wonderful experience, thanks to which I was able to learn the Python language and add it to my skills in other languages because I am interested in programming
- No

Qualitative Data Results

Qualitative data collected from all participants included CERD trainers, DOPS coaches, and teachers throughout their engagement in the teacher professional development communities of practices and post the experience through in-depth structured interviews. All the data was transcribed and anonymized before being analyzed thematically and the following themes emerged

Intrinsic Motivation: The qualitative data emphasizes the intrinsic motivation of teachers who reiterated that the project was valuable in and of itself, for them and for their students. Teachers thought it enabled and empowered them to prepare their students with knowledge and skills for success. As reported in the boxplots data, the narrow IQR, suggests that teachers and students recognized the significant value and benefit of peerScholar and Coder-Maker. The minimal spread in responses indicates a consensus on their perceived value of the combined experience. Additionally, teachers reported the relevance of the TPD to their practice and professional growth. As mentioned earlier in the document, teachers' motivation enabled them to overcome programmatic and contextual challenges. Following are two statements of teachers about their perception of the experience and their motivation.

"*It was a great experience, they were able to build-on each other's ideas, though the time was a bit tight. While the entire program was valuable, students tended to focus more on subjects that impact their grades*". Public School Teacher, Source, Post-Implementation Interview

"My students were proud of their work, being able to learn Python and finding solutions to a community problem. They wanted to learn more and more and be better at Python. All of a sudden, things had a different meaning for them". Public School Teacher, Source, Interviews

"The assessment tool we used was a great idea because it allowed students to evaluate each other, making them feel comfortable and open to sharing ideas. We were happy to see how motivated students were in the process. They accepted feedback well and were eager to hear what other groups thought of their work. This approach works well because students of the same age and level can assess each other in ways that are different from how teachers might, which makes the feedback more relatable and helpful". Public School Teacher

"We have enjoyed learning Python. It is important for us and we need to be better and learn advanced skills. It is important for students. They need those skills in computing but also learning to solve problems together. CoP engagement". Public School Teachers

Pedagogical Innovation: In challenging contexts, educational technologies often focus on providing access to technology, with limited emphasis on transforming pedagogy toward student-centered engagement. The theme that emerged is how they embraced instead of rejecting pedagogical transformation, overcoming the initial stress and tension and feeling confident to teach in new ways. Surprisingly, regardless of what was happening around them, they were able to embrace teaching coding, making, and engaging their students in peerScholar. They suggested using introductory features of peerScholar before engaging in more complex ones with readiness to learn more deeply Python, continue implementing STEM pedagogy and using peerScholar for peer assessment. Here are excerpts of teachers' interviews,

"My name is Amal, and I am a technology teacher who works closely with students on electronic projects using the Raspberry Pi. Recently, my students participated in a peer assessment day where they were tasked with evaluating their own work and that of other groups. The evaluation method presented to the students was highly effective, particularly because it encouraged them to give constructive feedback. This approach not only allowed students to identify the strengths of each project but also to suggest improvements in a positive and supportive manner. It was a great way to enhance their critical thinking and communication skills, fostering an environment of collaborative learning". Semi-Private School Teacher, Source, Post-implementation Interview.

"The peerScholar platform is a new and interesting idea that proved to be beneficial, making interaction between students easier. It allowed them to view each other's projects and give feedback anonymously, which encouraged them to present their work better and offer constructive, rather than negative, feedback, a crucial skill for students to learn. Both students and teachers enjoyed using it. However, the challenge was the number of points and criteria to consider, which made the process complex. I would prefer a simpler version, especially if we want to implement it in schools where time is limited." Public School Teacher, Source, Post-implementation Interview.

"The Coder-Maker course is important and provides us with skills and content to teach. It is so important for us, for our schools. We are in this century, Public School Teacher, Source, CoP conversation.

Commitment to their Profession: Throughout the engagement in the CoP conversations teachers

showed how deeply committed they were to their students' success and to their profession, even in the most excruciating circumstances. This corroborates across the data and the intrinsic motivation scale interquartile range (IQR) with most responses indicating a strong positive reception for the combined experience of CoderMaker and peerScholar. Here are excerpts of what two teachers reported.

"*Everything was great in the training. Students are excited to learn Python and to solve problems. I teach them Python from one computer connected to the projector. Then, they write the code on paper and we discuss which one is correct and why. For us to learn before teaching, it would be better if it was during summer vacation to take much more time to practice.* Public School Teacher, Source, Post-implementation Interview

"For me, it is like every time, we are enthusiastic but instead of this encouragement increasing, we feel it fading until it disappears. Other teachers did not continue. We started our school year with intensive meetings and promises but after that we did not get those, whether in terms of equipment, or the material resources, which were just ink on paper"... Public School Teacher, Source, CoP conversation.

Transferable Skills: Teachers found that the experience enabled their students to practice transferable skills and is a means to equip them with opportunities to apply computational thinking, critical and creative thinking to solve real-life problems, individualized and collaborative learning and mostly meta-cognitive skills which is so difficult to teach. They found that their students were more motivated and responsible toward their work and were astonished at their abilities to engage responsibly in peer assessment using peerScholar.

"This experience shows us that our students are capable and responsible. I never thought they could do peer review and give positive and constructive feedback. I was also surprised to see how they received constructive feedback. Usually, they take comments negatively. Here they listened and discussed how to do better". Public School Teacher, Source, Post-implementation Interview

"The course provided essential skills, like learning to program, to work and learn with others and to solve a problem as a group and more… after that, they learnt to do peer review and to listen to comments in a new way", Public School Teacher, Source, Post-implementation Interview

"PeerScholar pedagogy is in line with the new curriculum and provides more than peer review and assessment promoting individualized and self-directed learning skills, CERD Officials, Source, Post-implementation

Human-Centeredness: All teachers voiced, throughout the project, the experience provided them human values. Teachers reported sensing that the program instructors, IEA and peerScholar, genuinely cared about their work and its contribution to the research. They felt that they were valued and respected and their efforts were recognized, mentioning that the support, feedback and professional learning environment had boosted their morale. Here is an excerpt of teachers' unsolicited feedback given by a teacher at the end of the peer assessment day:

"We cannot compare the support, care, feedback and recognition we have had during this experience with IEA's trainers as compared to any of the other program we have engaged in, and we have been in many!" stressed the teacher." Public School Teacher, Unsolicited reflective feedback post-implementation.

This statement is important given the challenges mentioned earlier, the lack of resources, time, internet

and computers, at school to engage with.

Competences: All participants, teachers, trainers, coaches, students and CERD officials, clearly expressed the need to be more competent in all aspects of the program. They seemed to agree that the content and process of the courses contributed to their learning. Additionally, coaches expressed the need to be a step ahead of teachers to provide adequate support. While teachers and students appreciated classroom implementation content, they also requested to learn more deeply and be more competent.

"*We have benefited from learning Python…but we need to be better and learn more advanced skills".* CoP engagement, Public-school Teachers

"…*We learnt programming concepts and a new language which opened new horizons to integrate new technologies to implement interdisciplinary projects. We learnt how inquiry-based learning can be applied to teaching coding and solving problems and understood what AI is. But we need to be more competent and several steps stronger and ahead of teachers to be able to provide them support*. CoP, Coaches

"*The courses helped gain growing competences and the course pedagogy applies to aspirations of the new curriculum.* Trainers, CoP

Connectedness: Connectedness emerged as highly important to teachers. As shown in the boxplots, there was a positive shift in the connections between teachers, as well as between teachers and students. They explained how the program helped them amplify connectedness with peers. They appreciated having a representative of CERD in the program who engaged with them and helped to resolve programmatic challenges. Interestingly, they also mentioned making time for their students to connect with their peers to share their experience with others and the importance of giving such opportunities to all students. This also reflects the importance of not only being socially connected but enabling social connectedness at student level, to share and relate their experience with their peers. Here is one of their reflective comments.

"*The day was very important and beneficial for the students. Hands-on experience was key; without actively participating, they wouldn't have gained as much from it. When they returned to school, they eagerly shared their experiences with their peers, who became excited to join in future programs. It is an experience that all students can benefit from. The students not only benefited from the day's activities but also inspired others to get involved."* Public School Teacher, Source, Post-implementation Interviews

"*The conversations we had were helpful. I learnt from other teachers how they were teaching python to their students and how they found solutions to continue. Even the sessions during project work with students helped me".* Public School Teacher, Source, Post-implementation Interviews

Resilience: Teachers reported how they addressed the problem they faced mostly during the CoP conversations and shared how they mitigated those demonstrating remarkable resilience and creativity to overcome them. During feedback sessions, they reiterated that the timing of the courses posed initial difficulties, coinciding with their summer holidays and official exams. They had to juggle exam supervision during the day and course activities in the evenings, with some even missing webinars due to their involvement in grading exams. Despite these scheduling conflicts, they showed determination by catching up on missed content and persevering through the program. During the STEAM+H pedagogical course, they faced additional strain of committing to learning during the end-of-year holidays. Yet, they ultimately completed the

course, showcasing their dedication to professional growth and their students' learning. After completing the courses, teachers had to wait for approval letters, delaying the official start of classroom implementation. In addition, limited resources, logistical delays and political insecurity for schools in the South of Lebanon, compounded these issues. Teachers resourcefully adapted themselves, for those circumstances, conducting unplugged coding lessons using pen and paper and collaborating with school principals and parents when needed, or adapting the content for shorter school days. Their students' enthusiasm and active participation in coding projects, peer assessments, and prototype showcases underscored the impact of their efforts. During those conversations, the CERD program manager listened supportively and helped discuss solutions within the boundaries of what was possible. Aside from more time to learn, teachers requested additional classroom time.

Response to Research Questions

Does the Implementation Have the Pedagogical Impact We Hope It Will on Teaching and Learning? This report examines the pedagogical impact of the implementation, addressing the following sub-questions:

1. What is the interaction between peerScholar (pS) and Coder-Maker?
2. How do teachers perceive their own learning, the experience of working through the process, their motivation, self-efficacy, and sense of agency?
3. How do students perceive the learning experience? To what extent are they internally motivated in the process, and how does this influence their sense of agency and empowerment?
4. How and to what extent can innovation be diffused into the pedagogical process by early adopters in the Lebanese education system?

Pedagogical Impact: Exceeding Expectations

The pedagogical implementation exceeded our expectations in its impact on teaching and learning. Teachers and students embraced new ways of teaching, learning, and assessing, reporting an enhanced sense of agency. This empowerment allowed them to take control of their learning, project implementation, and assessment processes.

Teachers and students engaged in a complex learning experience despite significant contextual and programmatic challenges. They navigated unfamiliar content and processes, learning and teaching computational thinking, making, STEAM+H, and peer assessment. They used digital tools such as Raspberry Pi, sensors, motors, and the EdX platform. Subsequently, they guided their students in designing and creating their Minimum Viable Products (MVPs) and engaged them in peer review. Interestingly, despite the challenges, they found the experience enjoyable and intrinsically rewarding. A useful analogy is persuading someone to eat spinach for its health benefits, typically requiring external motivation, such as engaging narratives (e.g., cartoons portraying spinach as a source of strength). However, in this case, teachers and students not only accepted the 'spinach' but actively sought it out and enjoyed it.

This enthusiastic adoption, despite the hurdles, appears to stem from the perceived pedagogical relevance and value of the Knowledge-building experience. As SDT suggests, choice enhances autonomy,

which in turn strengthens intrinsic motivation (Deci & Ryan, 2015). Notably, participation was not entirely voluntary for all teachers and students, yet this did not negatively impact their motivation. This finding underscores the effectiveness of the peerScholar-enhanced version of Coder-Maker, which created a learning ecosystem fostering agency through autonomy, competence, and relatedness, further explored in the sub-questions below.

1. The Interaction Between PeerScholar and Coder-Maker

The integration of peerScholar with Coder-Maker was seamless and complementary. Teachers and students naturally transitioned to peerScholar upon completing their projects, uploading them for review and engaging in peer assessment. The results indicate that their combination enriched the teaching and learning, enabling both groups to engage deeply with transferable skills.

For teachers, this integration facilitated hands-on professional development. It equipped them to embed skills such as problem-solving, computational thinking, communication, collaboration, critical thinking, and metacognitive reflection into their teaching practices. The alignment between theory and practice helped them incorporate these essential skills, even in challenging circumstances.

For students, the synergy between Coder-Maker and peerScholar fostered an engaging, self-directed learning environment. They found the process motivating and immersive, practicing both technical and interdisciplinary skills. The boxplot results reveal that students highly valued peerScholar, particularly the peer assessment process, which deepened their engagement and reinforced their learning.

2. Teachers' Perceptions: Learning, Motivation, Self-Efficacy, and Agency

Teachers viewed the combined Coder-Maker and peerScholar experience as a significant professional development opportunity. It enhanced their instructional capabilities in coding, making, peer assessment, and STEAM+H learning. The boxplot results indicate high motivation but moderate self-efficacy. Teachers invested effort and felt confident enough in applying their newly acquired knowledge. However, they also expressed a strong desire for continued professional growth to deepen their competence.

Despite initial stress and the lack of time and resources available related to mastering new skills, the experience was highly rewarding. Through peerScholar's micro-learning model and the Coder-Maker Knowledge-building pedagogy, teachers felt equipped to model and scaffold essential skills for their students. They reported positive impacts on student engagement, particularly in peer review, communication, collaboration, and critical thinking. Ultimately, teachers reported a heightened sense of agency. They felt empowered to innovate in their teaching, creating a student-centered, reflective learning environment where technology and pedagogy align to foster deeper learning.

3. Students' Perceptions: Motivation, Agency, and Empowerment

Students perceived the combined Coder-Maker and peerScholar experience as highly valuable. They were deeply engaged and motivated, viewing it as an opportunity to apply knowledge in real-world contexts. Collaborative coding projects, coupled with peer assessment, significantly enhanced their intrinsic motivation

and sense of relatedness to peers.

Although some students initially reported stress, likely due to the responsibility of in-person peer assessment, they recognized that "*it was fun, enjoyable and a great experience*". The boxplot data indicates that students' autonomy and agency increased, though they identified a need to improve their competence. Despite feeling moderately self-efficacious, their motivation, interest, and enjoyment were exceptionally high.

Peer feedback through peerScholar helped students discover and unlock their potential, boosting their self-confidence. The iterative practice and feedback loops during peer assessment were instrumental in reinforcing their sense of agency. Overall, students felt empowered as active contributors to the learning process, developing essential cognitive, collaborative, and practical skills that prepare them for future learning and innovation.

4. How and to What Extent Can Innovation Be Diffused into The Pedagogical Process by Early Adopters in the Education System in Lebanon?

Early adopters, specifically, the teachers who sustained and completed the Coder-Maker and peerScholar experiences, play a crucial role in demonstrating what is possible and how pedagogical innovation can take root in the Lebanese education system. These educators exhibited the defining characteristics of early adopters: they were relatively risk tolerant, socially connected, enthusiastic, and optimistic about new products and technologies (Rogers, 2020). Beyond these traits, they demonstrated a heightened sense of agency, resilience, commitment to their professions and students which could be considered additional traits of early adopters in education.

However, while early adopters embody these traits, they often operate in defiance of systemic constraints that deter their peers from engaging in transformative professional development. For innovation to move beyond isolated instances and become embedded within the education system, systemic levers ought to be addressed. Systems Thinking (ST) highlights these levers, emphasizing institutional policies, resource allocation, professional development structures, and, most critically, the relationships and communication patterns that influence learning. Without structural support, such as administrative buy-in, access to EdTech tools, and sustained professional development, the innovative practices modeled by early adopters, risk remaining fragmented rather than being widely adopted. Additionally, teachers have emphasized that their motivation is deeply linked to feeling valued, both as individuals and as professionals in their respective subject areas.

Thus, while equipping early adopters with deeper competences is necessary, it is not sufficient to ensure meaningful integration. Embedding knowledge-building pedagogy at system level, providing resources such as time, space for collaborative learning, and flexible programmatic structures must also be coupled with relational conditions that empower educators. To the extent that these conditions are met, early adopters in Lebanon can act as catalysts, embedding innovative approaches into the pedagogical process and gradually transforming teaching and learning practices at scale.

Discussion

The combined experience of Coder-Maker and peerScholar within the Lebanese education system during a time of crisis illustrates the significant potential for integrating innovation into pedagogy, even under systemic and resource constraints. While these limitations posed challenges, educators and students deeply valued the experience, demonstrating high levels of engagement and motivation. The structured yet flexible design of Coder-Maker and peerScholar provided an enabling ecosystem that fostered collaboration, and knowledge-building around STEAM+H learning. As participants navigated these experiences, they not only overcame obstacles but also developed a stronger sense of agency, motivation, and purpose, key components of Self-Determination Theory (SDT) (Deci & Ryan, 2000; Ryan & Deci, 2017).

Self-Determination And Student Agency

peerScholar played a pivotal role in reinforcing students' self-efficacy by providing opportunities for peer assessment, constructive feedback, and reflection. This process directly supported students' autonomy, competence, and relatedness, the three core psychological needs identified in Self-Determination Theory as essential for intrinsic motivation (Ryan & Deci, 2017). By engaging in peer evaluation, students developed a deeper understanding of their contributions, which enhanced their sense of ownership over their learning. Literature supports this, as Joordens et al. (2019) highlight peerScholar's effectiveness in fostering both cognitive and socio-emotional development through structured peer feedback. The program's emphasis on autonomy and collaborative learning aligned with findings by Gao et al. (2020), who argue that traditional assessments often fail to capture critical thinking and problem-solving skills, capabilities that peerScholar successfully nurtured.

Similarly, Coder-Maker fostered knowledge-building and STEAM+H skills while emphasizing student agency. The program encouraged students to engage in goal setting, design thinking, and problem-solving, reinforcing their capacity to take initiative in their learning. While much of the technical skill development, including learning Python, took place in class, yet project work extended beyond the classroom. This extension allowed students to explore real-world problems of their choice, unconstrained by traditional classroom structures, enabling creativity to flourish. The results suggest that when students see their learning as relevant and meaningful, their engagement becomes deeper and more intrinsically motivated (Deci & Ryan, 2015).

Diffusion of Innovation and Early Adopter Characteristics

The adoption and sustained engagement of teachers in Coder-Maker and peerScholar reflect Rogers' (2003) Diffusion of Innovations Theory, which posits that innovations are more likely to spread when adopters perceive them as valuable, compatible with their needs, and beneficial for their professional practice. The teachers in this study demonstrated key traits of early adopters: they were relatively risk-tolerant, socially connected, and enthusiastic about integrating new technologies and pedagogical approaches (Rogers, 2020). Beyond these characteristics, they exhibited a heightened sense of agency with resilience, intrinsic motivation, and a strong commitment to both their students and their profession. They also valued respect and recognition, factors that played a role in sustaining their engagement and willingness to innovate.

As early adopters, these teachers faced systemic barriers that deterred their peers from engaging in similar professional development. According to Rogers (2003), successful diffusion requires not only willing adopters but also favorable systemic conditions. While these educators demonstrated agency in circumventing institutional obstacles, wider adoption necessitates systemic support to ensure innovations are not isolated but rather diffused across the education system.

Systems Thinking and Scaling Innovation

For early adoption to transition into widespread educational transformation, systemic levers must be addressed. Systems Thinking (ST) provides a useful lens for understanding how institutional policies, resource allocation, professional development structures, and relational dynamics influence the scalability of educational innovation. A critical factor in sustaining motivation and engagement, as highlighted by SDT, is feeling valued and supported within one's professional environment (Ryan & Deci, 2015). Teachers emphasized that both their personal recognition and the perceived importance of their subjects played a role in their continued commitment. This insight aligns with research by Priestley (2015) and Biesta & Tedder (2006), who argue that agency is not merely an individual trait but is co-constructed through interactions with one's environment.

School leadership, policy support, and effective communication among stakeholders are essential for sustaining intrinsic motivation and, by extension, educational innovation (Ryan & Deci, 2015). Teachers' ability to facilitate peer assessment in peerScholar and lead STEAM+H projects such as Coder-Maker demonstrate that when provided with Knowledge-building conditions, educators themselves develop transferable skills and confidence in integrating innovative pedagogies. This mutual development of agency across students and teachers highlights the transformative potential of such approaches.

Implications for Educational Practice and Policy

These findings have significant implications for scaling innovation beyond early adopters equitably in the Lebanese education system. peerScholar and Coder-Maker are designed by educators to eliminate barriers associated with resistance to innovation. Barriers include high-cost technologies, platforms, equipment etc. pS provides a robust, evidence-based and accessible platform that requires very low connectivity. Furthermore, Coder-Maker courses are open source and run on IEAlearning platform. The program is designed to enable students to create prototypes from what is around them without relying on expensive technologies. As Barton et al. (2017) argue, coding and making can advance equity in education by legitimizing skills such as creativity, engineering design, and iterative problem-solving skills. Barriers also include teacher resistance which was addressed through a situated teachers professional development designed to scaffold Knowledge-building enabling teachers to feel competent enough to implement in their practices. Teachers combined, in and out of the classroom, without undermining student agency and creativity, which arguably is significant, considering that making could become overly circularized in ways that eviscerate its creativity (Bevan, 2017).

Additionally, to embed educational innovation into mainstream practice, it is essential to cultivate environments that respect teachers' and students' autonomy, support their competence, and foster strong relatedness within the educational community. This requires: 1) **Structural support**: Providing teachers with

administrative buy in, access to resources, and sustained professional development. It is worth noting that support was instrumental to teachers' feeling confident during the implementation. 2) **Relational support**: Strengthening communication and collaboration among educators, students, school leadership, and policymakers to create a culture of shared purpose and respect. 3) **Recognition and Valuation**: Ensuring that teachers feel valued and that their subjects are recognized as integral to students' broader development. peerScholar and Coder-Maker illustrate how Knowledge-building experiences can foster a heightened sense of agency, motivation and transferable skills. The interactive nature of peerScholar offers a meaningful way to assess STEAM+ H competencies, an area often overlooked by traditional assessment methods (Dochy et al., 1999; Liu & Carless, 2006). As education systems increasingly prioritize innovation-oriented learning, such assessment models provide a promising alternative for evaluating transferable skills.

Conclusion

The research examined the implementation of Coder-Maker and peerScholar within the Lebanese educational system during a period of intense crisis. Specifically, it investigated how the acquisition of transferable skills, supported by peer assessment and STEAM+H learning, enhanced teacher and learner agency. Beginning with 10 teachers and concluding with seven teachers and 29 students, the study followed a structured process: teachers first learned coding, making, and peer assessment before guiding students and engaging them in collaborative problem-solving, designing and peer assessing their MVPs using peerScholar.

Findings revealed that integrating coding, making, and peer assessment within a structured, yet flexible Knowledge-building pedagogical framework fostered a strong sense of agency among both teachers and students. Consistent with Self-Determination Theory (Deci & Ryan, 2000; Ryan & Deci, 2015), participants displayed high intrinsic motivation, autonomy, and competence, which contributed to their sustained engagement despite systemic constraints. Teachers and students alike recognized the value of these innovations, reinforcing Rogers' Diffusion of Innovation Theory (2003), which emphasizes the role of perceived relevance in the adoption of new practices. Teachers exhibited characteristics aligned with early adopters, showing enthusiasm, adaptability, and a strong sense of professional commitment.

This study underscores the potential of integrating computational thinking and transferable skills into teaching, learning, and assessment in Lebanon. Importantly, peerScholar's role in fostering peer assessment, collaboration, and critical thinking positions it as a valuable tool for assessing STEAM+H competencies, an area often overlooked in traditional assessment methods (Gao et al., 2020; Dochy et al., 1999; Liu & Carless, 2006).

The research highlights the necessity of an enabling ecosystem that supports teachers and students, including professional development, policy alignment, and sustained communication channels across the education system. As Biesta and Tedder (2006) and Priestley (2015) argue, agency is cultivated through interaction with one's environment, and this study provides evidence that fostering connectedness and valuing teachers' professional growth are essential to sustaining educational innovation at scale.

While these findings demonstrate the transformative potential of Coder-Maker and peerScholar in fostering meaningful and future-oriented educational experiences, further research with a larger sample is

needed to explore how these innovations can be scaled effectively. The insights gained from this research provide a foundation for policy recommendations aimed at integrating coding, making, and peer assessment within the Lebanese education system. In an era where digital technologies and artificial intelligence are reshaping education, this study highlights the urgency of moving beyond superficial technology use to cultivate deeper, more meaningful learning experiences.

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