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Scaffolding computational thinking: Pre-service teachers learning through Scratch programming

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Abstract: This study explores how a technology-rich learning environment, integrating various scaffolding strategies, supports pre-service teachers' (PSTs) development in computational learning using Scratch. A design-based research methodology was applied with 25 second-year PSTs from diverse disciplinary backgrounds. A qualitative research paradigm was used for analysis. The learning environment was intentionally designed to promote autonomy and a sense of responsibility among PSTs through engagement in computational tasks and access to both social and material scaffolds. Social scaffolds included interactions with external individuals, communication with the course lecturer, peer support via a WhatsApp group, and general collegial exchange. Material scaffolds comprised a digital Scratch workbook, recorded class sessions, and system-generated feedback. Findings indicate that these scaffolds significantly contributed to PSTs' agency and supported the development of independent learner identities. The study concludes that a diverse and flexible digital learning environment, offering multiple modes of support, enhances learners' ownership of their learning process and autonomy. These insights suggest that incorporating both social and material scaffolding in teacher education programs can effectively foster computational thinking and promote self-directed learning, offering practical guidance for educators designing digitally mediated learning experiences.
Keywords: *Design-based research, Pre-service teachers, Scaffoldings; Scratch, Teacher education.*

1. Introduction

Future trends in the field of society, technology and economy impact the world of education and challenge researchers, education practitioners, and teachers to provide an appropriate educational response to the changing reality. Although we are now deep into the 21st century, the anticipated change in teaching methods has not yet been occurred. The learning process still takes place within the boundaries of the classroom at a given time, and values such as cooperation, personalization, relevance and dialogism are not sufficiently manifested in schools. The challenge is even stronger in teacher education colleges, where the commitment to meaningful learning processes is greater, aiming to serve as model for pre-service teachers [hereinafter – "PSTs] so that they act in such a way as future teachers [1].

The OECD [2] indicated several concerns regarding education. Two of these concerns specifically relate to creativity, problem-solution and efficient use of technology. These concerns are added to serious questions that preoccupy education practitioners and researchers. For example: How can independent thinking be promoted among learners in schools and in higher education? How can we develop autonomous learning and enhance student agency so that responsibility for the learning is shifted to the learners who will decide what and how to learn. Rich technological environments and digital games have the potential to promote this type of learning [3, 4].

This study constitutes a modest step in this direction. It describes the design of a learning environment in which PSTs practice teaching in a technological environment that is rich with various

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scaffolding types. The practicum includes familiarization with the Scratch software and development of a learning game by means of this software. The learning process is built so that in addition to getting acquainted with the programming language, PSTs practice and develop awareness of pedagogical principles. For example: high-order thinking, active learning, cooperation, problem-solving, and so on, all being principles related to learners in the 21st century. Learning in such an environment facilitates a discussion about bigger questions that engage in the way we are learning in a changing world, as well as in our role as teachers in this context.

This study particularly aims to identify the scaffolds perceived as the most meaningful learning resources for PSTs. Since Scratch, the content knowledge introduced in this learning environment, was new and unfamiliar to PSTs, the lecturers offered various types of scaffolds—both tangible and emotional. These included, among others, feedback about the software or a personal talk with a course lecturer, and the PSTs could choose by themselves the scaffolding they needed. In other words, the PSTs were required to think independently throughout the course which scaffold or resources they wanted to choose so that the latter would promote them to succeed in the programming challenge. Thus, the learning environment offers various learning resources, allowing the students to decide how and when to learn. This study aims to explore the way by which PSTs function in a rich technological environment, as well as the implications for the design of their learning processes in the context of teacher education program.

The Literature Review opens with a wide overview of the theoretical framework of learning. Then, it presents the concept "scaffolding" underpinning this study. Hence, the terms various researchers have attributed to this concept are intertwined, e.g., mediation tool, symbolic/cultural tool, and resource. This study considers these concepts as scaffolds erected for learners in a given learning environment. The last two themes of the literature review will focus on computational thinking and specifically, scaffolds in technological environments in the context of teacher education.

2. Literature Review

2.1. A Socio-Cultural Viewpoint of Learning

The Socio-Cultural Theory, conceived by Vygotsky and Cole [5] focuses on social interaction as pedagogy that supports learners' cognitive development. Vygotsky argues that human activity requires auxiliary aids, such as symbolic psychological tools and means of inter-personal communication. The term 'psychological tool' is analogous to the material tool that mediates between the person who performs the action and the person who receives the action. Psychological tools can be manifested by various ways, e.g., symbols, formulae, texts, tests, graphs, and others. Their use is oriented inwards and intensifies human cognitive ability by applying higher-order mental functions [6]. These tools are defined later as scaffolds (see extensive review in the next section).

Herrenkohl and Wertsch [7] expand the discussion of Vygotsky's concept regarding the mediation of human actions by tools or indicators. They underscore the tight relationship between the mediated action, the contexts in which it takes place, and the mediating actions (scaffolds). The researchers posit that the action is usually target-oriented and is shaped by the mediating tools, the use of which stems from the individuals' independent intention. Consequently, human action cannot be separated from the individuals and the situation in which it transpires. Fishman and Herrenkohl [8] refers to the tools that mediate the learners' action as cultural tools. According to their definition, a cultural tool (scaffold) cannot be tangible like a book or a thinking tool such as problem-solving procedure. During the learning process, the less-experienced learners internalize the cultural tools and social competences from the common space that is external to their internal space, by means of an internalization process. The relationships between the learners and the scaffolds can be characterized in terms of mastery or appropriation. Mastery involves the knowledge of using the tool (knowing how). Conversely, appropriation involves both independent thinking with the tool (knowing why) and the perception that the tool is legitimate, logical, and essential. One of the aims of developing independent learners is to assist learners in reaching the level of appropriation. These terms facilitate the conceptualization of the actions that PSTs perform with the available tools, as well as the way they integrate the tools into their actions. Based on the importance of acting with the mediating tools, the analysis units are set by the learners' actions through the mediation of the tools and with the help of teachers in their environment and will be encoded according to them. Thus, we acknowledge the unique needs of PSTs and their abilities, motivation, and a sense of ownership over one's learning, i.e, student agency [9, 10].

2.2. Constructionism: A Learning Approach Centered on Creation

Grounded in the constructivist premise that knowledge is actively constructed through the process of building cognitive structures as a result of learners' interactions with the world, the constructionist theory posits that knowledge acquisition is inherently intertwined with the act of creation. Holbert, et al. [11] further elaborate that constructionism serves as a conceptual framework for learning, emphasizing the understanding of concepts through the collaborative creation of artifacts, which necessitates learners applying their comprehension in the construction process itself. Notably, constructionism defines learning not solely as the development and application of knowledge, whether mental or practical, but also recognizes the process of constructing artifacts as a fundamental aspect of the learning experience. Consequently, artifacts, tools, and social interactions not only impact learners, but are also influenced and modified by learners. Engaging in a process of learning through creation requires students to employ advanced cognitive functions and skills, such as creativity, critical thinking, problem-solving, and decision-making.

Resnick [12] in collaboration with his team at MIT Media Lab, devised an environment that imparts an understanding of the principles of computational thinking to children. This environment aligns closely with the constructionist approach to education and incorporates four key elements known as the four P's: Projects, Passion, Peers, and Play. These elements are embodied in Scratch environment, where learners create projects utilizing a visual system of simple commands presented as tiles, reminiscent of Lego blocks. The environment provides resources such as videos, animations, and games to support the creation process.

2.3. Scaffolds and Mediation

The term "scaffolds" is identified with the socio-cultural approach to learning, according to which action and doing are an inseparable part of the activity of developing new knowledge. Wood, et al. [13] describe the classic definition of scaffolds as support from adults during the learning process. This is a measured and accurate support that assists learners in the performance of a task or the solution of a problem in a way that is not possible without it. Such support can be offered by illustrating the problem-solution or by emphasizing important features that can lead to the performance of the task. This description underscores the responsibility of the adult (e.g., a teacher) to provide appropriate scaffolds. The technological development, presentation of the knowledge, and access to various information sources, have expanded the definition of scaffolds, and included additional support by means of software tools, games, and graphical representations. This liberal perception of the scaffolds is controversial [14] raising numerous questions. For example: Can every collection of instruction materials, teaching strategies, or structured activities be considered as scaffolds? Is every type of support called scaffolding? What is the division of responsibility between scaffolds and the teacher in the learning process? To what extent can a technological tool diagnose what learners need as adults do? Is what the tool provides truly a scaffold? What is actually the meaning when we say that the tool has become a scaffold for the learner?

While attempting to cope with these questions, Puntambekar [15] suggested expanding the classic meaning of the term scaffolds to a situation with a continuous variety of teaching designs, integrated and ordered in diversified social and material supports that assist learners. For that purpose, they coined the term distributed scaffoldings. Reiser and Tabak [14] distinguish between three types of relationships between distributed scaffoldings: differential scaffolds, redundant scaffolds, and synergistic scaffolds. Differential scaffolds are designed to meet varied learning needs. Redundant scaffolds are different means of support, oriented at the same need, yet at different points of time during the learning, in order to provide different levels and support accuracy. Synergistic scaffolds are supports that act simultaneously for the same needs, intensifying each other and creating a strong impact on learning. They intensify each other, creating a strong impact on the learning

A situation of distributed scaffoldings highlights the need for orchestration between the scaffolds and for creation of coherence between them. In this situation, teachers are perceived as responsible for the orchestration of the scaffolds [16, 17] for the purpose of helping the learners to recognize and realize their potential. One way of doing that is by using meta- scaffolding [18]. Meta-scaffolding implies one scaffold upon another. For example: teachers indicate what learners should focus on when solving a problem, which tool to use from the environment, or which aspects of the tool are more or less relevant to the solution.

Even if they have been meticulously planned, not all the tools and scaffolds will necessarily leverage the learning. Reiser and Tabak [14] distinguish between two mechanisms that scaffolds should encompass. One mechanism originates in the structure of the scaffold, the role of which is to simplify the problem, be transparent to the learners, and render things easier for them. Another mechanism is the creation of engagement that leads learners to focus on the conceptual aspects of the task and, as a result, learn from experience. Broza and Kolikant [16] found that, in addition to a synergist effect of resources in a rich environment, there are resources that lead to a destructive effect in cases where a tension is formed between the teachers' academic aims and the independent uses that the learners had developed with the tools in their environment.

2.4. Computational Thinking: A Conceptual Framework for Problem Solving

The term "computational thinking" (CT), initially coined by Papert during the development of the Logo programming language, aimed to find a way to engage students in mathematics and geometry by utilizing programming as a means to acquire mathematical knowledge. The concept of CT was later redefined to encompass problem-solving, system design, and understanding human behavior, drawing on fundamental concepts from computer science [19]. Key processes and skills associated with CT include problem formulation, data organization and logical analysis, data representation through abstraction using models and simulations, generation and evaluation of multiple solutions, problem decomposition into sub-problems, implementation of potential solutions, and examination of outcomes through debugging and generalization. Günbatar [20] expanded on the social aspects of CT, asserting that the CT approach emphasizes the acquisition of broad and multidisciplinary skills and knowledge that can be applied in various contexts. It is important to note that CT is not limited to programming alone. In addition to cognitive abilities, the skills utilized in this context encompass not only computer science principles but also social skills that foster learning, such as teamwork and effective time management.

There is existing literature that provides evidence of various effects of technology-based interventions on pre-service teachers' (PSTs) motivation and self-efficacy. For instance, in a study conducted by Gleasman and Kim [21] an intervention program was examined that utilized Scratch programming as a tool for teaching elementary mathematics in a conceptual manner. The researchers investigated the PSTs' ability to connect computational thinking with mathematics, particularly their capacity to design lessons that taught mathematics concepts through programming. The results from surveys showed a slight overall increase in participants' attitudes towards computational thinking and its integration into mathematics instruction when comparing pre and post interventions. Notably, the PSTs' confidence in programming significantly improved.

Another study by Butler and Leahy [22] focused on PSTs' understanding of computational thinking through engagement with a digital learning environment like Scratch. They discovered that PSTs were able to establish connections between the pedagogy of constructionism and computational thinking.

2.5. Scaffolds in Technological Environments in the Context of Teacher Education

In the context of teacher education, teacher educators (hereinafter – "TEs") and peers can provide appropriate scaffolds [23]. Among scaffolds that are frequently used in teacher education, one can find question posing, the use of verbal cues, reinforcement, prediction, paraphrasing, and orientation [24]. Scaffolds that are used in online learning environments, are commonly categorized as: conceptual scaffolding, including clues that guide learners towards the solution; coaching comments, i.e., strategies or heuristics in a certain context; feedback; reflection that encourages learners to perform self–monitoring; and modeling, whereby teacher educators present an example for similar situations. Research findings have found that PSTs in online learning environments where scaffolds were provided, were more active and conducted more meaningful discussions than PSTs in online environments without any scaffolds, such as comments and feedback from a TE [25]. Apparently, meta-cognitive scaffolds were extensively studied, since they were found to be most effective in virtual learning environments [26].

2.6. Method Design of the Learning Environment

Description of the course learning environment design presents the rationale of the development and processing of the course.

The Development Rationale – High-Order Thinking by the Design of Games

Games are a natural way of learning in that they offer opportunities for creative thinking, problem-solving, coping with conflicts, drawing conclusions and more [27]. Learning through the design of games can be applied to any topic and at any level, and it enables the application of a wide range of thinking and learning skills. Studies have shown that learning by the design of games embodies many advantages: it improves cognitive functioning and attention; enhances critical reflection, problem-solving, and decision-making; implements constructivist principles of knowledge building and promotes reflection about daily experiences [28]. Many researchers have emphasized the contribution of game design to the development of creative thinking and designer thinking. Through collaboration and shared design of games, learners can be more reflective regarding their work [29].

The design of games in education is most common programming education. The development environment in "scratch" continues Papert's development and naturally supports learning processes by creation. This is due to the fact that by its very nature it is a game-oriented environment that offers experiential and inquisitive learning, during which learners enjoy the freedom to play with ideas, program them by means of simple commands, and examine the results. The environment allows learners to invest energy and thought in solving the problems that they face, inviting learners to discover methods of solution and strategy in an enjoyable way [30]. The value added by the experience with this learning process is not embodied only in the familiarization with the programming language. Rather, it is encompassed also in the experience with learning processes of higher-order thinking that encourage active participation of the learners, collaboration, logical thinking development, coping with a big problem by its decomposition into smaller problems, identification of common solutions to common problems, etc. This environment facilitates a discussion about bigger questions that relate to the way we are learning in a changing world, as well as our role as teachers in this context.

The rationale underpinning the course focuses on the contribution of computer games integration into the learning experience, and on the question of whether the transition from a "player" to a "designer" makes the learning more meaningful. During the design of the course, we applied the theoretical framework of learning in a resource-intensive environment. This environment observes the learners' interaction with the entirety of the learning environment, underscores the importance of teachers' mediation, as well as defines the relationships between teachers, learners, and mediating tools, together with the learners' familiarization with the theories.

2.7. The Course Design

As this was the first implementation of the course, the lecturers had only preliminary knowledge regarding the PSTs' sense of self-efficacy in learning programming (computational thinking). Therefore, the lecturers anticipated the need to provide both technical and emotional support.

The course consisted of three main modules:

1. The first module (four lessons, each lasting 90 minutes) focused on familiarization with educational games, hands-on practice, and discussion of the learning experience, including the challenges and dilemmas involved in integrating computer games into school teaching.
2. The second module (four lessons) introduced game generators with structured patterns, as well as basic Scratch programming for animations and dialogues.
3. The third module (four lessons) centered on project design: working in pairs, planning and programming a game, presenting it in class, and receiving peer assessment. PSTs were able to choose the discipline, grade level, and type of game they wished to design.

Theoretical aspects of the course, as well as PSTs' perceptions and attitudes towards game-integrated teaching, were addressed through recorded presentations, short papers, and TED lectures uploaded to the course website. PSTs were asked to read, practice digital games, and analyze their playing experiences in light of the empirical literature, using collaborative tools such as Padlet and Google applications.

Our main goal was to support the process of developing the final project, which posed a challenge due to the participants' physical distance. The most significant changes in course design were implemented in the second and third modules. To promote self-determined learning, we created several virtual learning spaces, enabling all PSTs to express their voice and choose how to learn. Anticipating potential difficulties and concerns about managing the workload for the final project, we conducted coding instruction as synchronous Zoom lessons. These lessons were recorded and uploaded to Moodle, allowing students with different learning styles to watch at their convenience, practice the skills, or participate live with guidance from the lecturers.

Additionally, we launched a WhatsApp group and established a collaborative communication channel for questions and answers, as well as personal email support. Another resource available in the environment was the "Code Plus" textbook, published by the Center for Educational Technology, which provided specific instructional content. All these tools were intended to directly support the development of the final projects. In addition, we launched a reflective blog in which PSTs were asked to freely describe their feelings about their learning methods, discuss difficulties encountered and solutions found, and indicate how confident they felt with the new programming language. This tool was designed both to encourage PSTs to reflect on their learning process and to help lecturers better understand their students and establish a personal connection throughout the course.

Each lesson was dedicated both to teaching a new coding action and to discussing difficulties and mistakes from previous tasks. To enhance learning, PSTs shared their screens, demonstrated their progress, and discussed successes and errors. Throughout the course, we emphasized the multiple resources available in the learning environment (meta-scaffolding), including peers, lecturers, the textbook, session recordings, the WhatsApp group, and telephone consultations with lecturers. All these supports aimed to strengthen PSTs' resilience in meeting the challenges of the final projects and to promote their sense of self-efficacy, even in the absence of face-to-face interaction. As a result, PSTs were encouraged to develop awareness of the learning strategies and resources most suitable for them during this challenging period. As noted, participation in demonstration lessons was optional, and attendance at synchronous sessions varied from session to session, averaging about half the class. Each PST could choose to learn with a lecturer, from a recording, from the textbook and peers, or by combining these methods. We made extensive use of meta-scaffolding, conveying the message that all PSTs were entitled to find the space and resources that best supported their progress toward designing a learning game with Scratch. In cases of difficulty, we intentionally referred students to available resources in the environment before offering direct solutions.

2.8. Research Questions

1. What are the main scaffolds (learning resources) used by the PSTs in the Scratch environment?
2. What characterizes the PSTs' learning process in this environment?

3. Methodology and Research Design

This study was conducted according to the Design-Based Research methodology in the sciences of learning. This approach focuses on the complex relationships among learners, the learning environment, and the types of actions performed [31]. The aim is to understand the essence and conditions of learning as it unfolds in context, emphasizing the continuous interaction between learners and their environment. Unlike research that is based on controlled laboratory experiments, design-based research constitutes a methodological framework that takes into consideration the complexity of the system involved in the study, as well as the multitude variables, some of which are known in advance and others that emerge during the study. Design-based research is usually conducted in several rounds to examine the effects of learning environment design, revise and update the environment, refine hypotheses, and conduct further iterations. The present study describes the findings from the first round.

A rich learning environment makes the learning in class more complex, since it comprises many scaffold types in many types of interaction. Consequently, the classroom becomes a complex field of research. Due to the complexity of the learning process in the environment, we decided to use additional case-study methodology [32]. A case study facilitates identification of the learning process and all its complexity in the natural environment and, yet, encompasses all the players associated with the process itself.

4. Research Population and Data Collection

Twenty-five second-year pre-service teachers (PSTs) from various disciplines participated in this study (23 females and 2 males; mean age = 22 years).

In order to reinforce the reliability of the research findings, three research instruments were triangulated: a research diary kept by one of the course lecturers, 25 end-of-course assignments, and 25 reflexive blogs posted by each of the course participants. The general instruction for writing the reflection in the blog was: "Please record the learning process. Think about yourself as a learner. What was difficult, what was easy? To what extent do you feel free to try functioning in the Scratch environment? Do you manage to challenge yourself? How do you cope with difficulties? To what extent do you feel you can teach to learners all the actions we have performed until now?" And so on and so forth.

Due to ethical considerations, all the PSTs' materials were analyzed and processed after completion of the course and after receiving the score of the course.

5. Data Analysis

A qualitative research paradigm was adopted, using Nowell, et al. [33]. An inductive thematic analysis was performed to map and analyze students' use of scaffolds. The qualitative analysis included coding of all the data. At the first stage, the categories were obtained mainly from the reflections, the final reports, and the lecturers' diary (emic). The second step was an a-priori detection of categories (etic), based on the research findings of Puntambekar [15]. At the next phase, the themes were reviewed by all the researchers for agreement purposes. The researchers discussed the passages related to each coding category, reaching an intercoder agreement of 90%. To ensure validity, each researcher then shared the passages she interpreted as illustrative of a given category.

6. Findings

Learning in the environment, and noted that the course was different from any other course at the college. The emphasis of their reflections varied. For example, some PSTs initially expressed apprehension about programming with Scratch. However, as the course progressed, participants reported increased confidence and a sense of freedom to create and challenge themselves, indicating high motivation for learning in this environment. This section presents two key themes in compliance with the research questions and the categories they include. The first part examines the prevalence of PSTs' use of distributed scaffolds in the environment, and the second part characterizes the PSTs' learning process in the environment.

6.1. Choice of the Scaffolds in the Environment and the Way of Using Them

This theme presents the prevalence of use of the different scaffolds. Based on Puntambekar [15] the scaffolds were divided into two categories: (a) scaffolds characterized by social supports, such as: the course WhatsApp group, personal talk with the lecturer (via Zoom or telephone), help of a peer in the course or referral to an external body; and (b) scaffolds characterized by material supports, such as: feedback about the Scratch software, a digital textbook that teaches the Scratch software, and recordings of the learning sessions.

Table 1 presents the scaffolds and the prevalence of their use.

Table 1.
The prevalence of the use of scaffolds distributed in the environment.

PST number	Scaffolding characterized by social supports				Scaffolds characterized by material supports			Total tools' used By PST
	External help	talk with lecturer	WhatsApp group	Peers	Digital scratch book	recordings of class sessions	Feedback from scratch	
1.	X			X	X			3
2.		X		X		X		3
3.		X		X	X			3
4.	X							1
5.					X	X		2
6.							X	1
7.		X					X	2
8.		X						1
9.	X						X	2
10.				X	X			2
11.		X		X				2
12.						X		1
13.		X			X			2
14.		X		X	X			3
15.				X				1
16.		X		X	X			3
17.		X		X	X		X	4
18.		X			X		X	3
19.							X	1
20.							X	1
21.	X	X			X		X	4
22.						X		1
23.		X			X	X	X	4
24.		X				X		2
25.				X	X			2
Total uses for each scaffold	4	13	0	10	12	6	9	

Table 1 illustrates that the most common scaffolds, in decreasing order, were: talks with the course lecturers, a digital textbook for learning Scratch, and course peers. The fact that the most frequently used resource was contacting the course lecturer may reflect PSTs' conventional perceptions, viewing the lecturer as a content expert with the solutions. Alternatively, this frequent use of human scaffolds may indicate a need for emotional support, as observed by the lecturers during course design. However, the lecturers did not immediately solve the problems, but rather referred the PSTs to possible meta-scaffolds. The digital textbook and peers appeared to be the most accessible scaffolds, and thus served as meaningful resources "with which to think." Moreover, there were scaffolds that did not appear in the environment and the PSTs initiated their use in an independent way, e.g., Internet sites or help by a friends/relative. There was also another resource that was not used at all, i.e., the WhatsApp group. This might be due to the fact that a more intimate rather than communal support was needed in this context. Or, perhaps, the WhatsApp platform was less suitable for programming support since it required accurate verbal formulation of a challenge, whereas the Zoom platform was more suitable in this respect. These findings imply that the PSTs were entirely responsible for deciding whether or not to use the available scaffolds. They prioritized their choices and devised creative solutions, sometimes implementing independent scaffolds that were not part of the environment.

Furthermore, the average number of applied tools was two, attesting to a limited number of scaffolds, although the number of scaffolds offered by the environment was high.

The evidences cited below illustrate the difficulties that the PSTs encountered at the different stages of the programming, as well as the use of leading supports when they were stuck, as demonstrated in their end-of-course assignments. Miriam describes her requests for help from her peers, emphasizing the importance of the trial and error when she tried to succeed. This is a very important norm that is typical to the world of games and, hence, its contribution.

Miriam: "When I need help, I turn to my peers (via Zoom or telephone) and we consult and help each other during the learning. For example, for this lesson we needed new knowledge that, for me personally, was less clear from the beginning, from previous knowledge. Consequently, I got help from my peers. In addition, the process required trial and error-you make mistakes and learn until you succeed".

Sharona describes well the confidence she received from the lecturer as an emotional scaffold, combined with a content-oriented scaffold in the process of learning:

Sharona: "When I encounter a difficulty, or come across a point that I have missed in the lesson and cannot perform the task properly, I know that I can always turn to the lecturer, who will point out what I should look for and where I will find the origin of the mistake."

For Anita, the solution for coping with a difficulty is the use of the course digital textbook: *"When I encounter some difficulty that is connected to Scratch, I open the digital book and go over the explanations again."*

6.2. A Learning Process that Develops Student Agency

The content of the course was entirely new to the learners and constituted a challenge for them. They found themselves thinking which resources or scaffold in the environment could assist them in coping with the challenge. Such situations demonstrate the PSTs' ability to manage themselves within the richness of the environment and prioritize what suits them and what suits them less. As indicated in the context of this study, the lecturers persisted in the use of meta-scaffolds while referring the learners to the numerous scaffolds in the environment, in order to encourage them to cope by themselves. The themes described below constitute an infrastructure in the process of the promoting learning – student agency: learners' inner responsibility, relationships of trust, and autonomy.

6.3. Inner Responsibility for Learning

Findings of this study might indicate that the physical distancing and free time allocated for practice enhanced the PSTs' ability of independent learning out of an inner responsibility for complying with the expected product. More than once we have noticed that when teaching F2F, the PSTs are inclined to immediately turn to the lecturer when they are not sure or have a question, even before coping with the problem solution. Silvie described it well in her reflection:

"I am sure that if the lessons had been taught in a frontal manner, they would have been harder and noisier. At the beginning, learning the Scratch software is not easy and everyone needs, first of all, to experience it by themselves. This enables learning, enables lack of success, and then, one can ask how to do it."

6.4. Relationships of Trust and Autonomy

Some PSTs preferred learning completely independently through the distributed scaffoldings, without attending the synchronous sessions. The researcher diary illustratee that the lecturers felt "*that there was here an independent learning that we had a difficulty to understand its quality and assess it through the learning process*".

Nevertheless, the lecturers expressed full trust in the learning process and in granting autonomy to the PSTs. They perceived their role as promotion of innovative teaching modeling, provided the PSTs complied with the ultimate product of developing a game. Excerpts from one of the lecturers' diaries, reinforce this aspect:

"When talking with the PSTs, we realized that the environment allowed them to work independently, since it assisted them in the assessment of themselves while learning… Either the game worked or not." This was the advantage of the technological tool in this context.

The quality of the independent learning was measured at the stage of the end-of-course assignment that required an integration of all the actions that had/had not been learned in the course and were found important for the participants for the purpose of designing a satisfactory product for them. The last two lessons of the semester included presentations of the projects. Figure 1 demonstrates a screenshot from one of the PSTs' projects and its code (on the right).

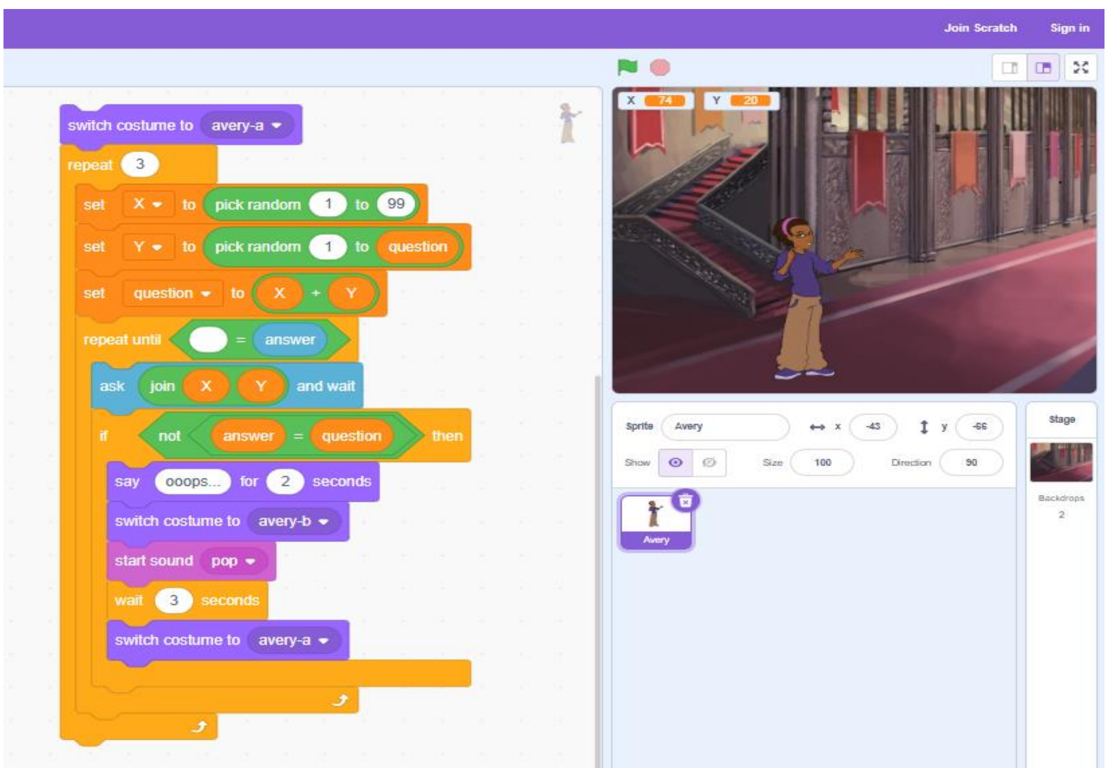

Figure 1.
Screenshot from final project on Scratch program.

The lecturers' feeling following the presentations reflected the coping with the challenge while using the multiple resources in the environment:

"Students were engaged in a collaborative process, relying on each other's created codes. They encountered problem-solving situations when their games didn't work and had to identify incorrect commands. These practical experiences enabled them to grasp the essence of high-order thinking, involving integration of concepts. They received assistance from various resources available in the environment, including the course textbook, peers, and lecturers. As a result, their responsibility for learning increased, and they effectively utilized the available resources".

Below is another evidence from the researcher diary regarding the environment that supported the independent learning and the sense of responsibility for the progress in the learning process:

"The environment allowed the PSTs to exhaust their capabilities. Some of them reached really far, while others did what they could, exerting a reasonable effort. All of them found their own place and the limit of their ability. I decidedly felt that they had shattered their own glass ceiling… I did not believe that these would be their product".

Silvie supported the lecturer's feeling:

"Once I started working on the software more by myself, I realized that it was not so difficult. I think that after starting to create things, I started feeling greater freedom to create and qct in the environment, as well as challenge myself".

7. Discussion

The rapidly evolving, multi-dimensional technological reality expands learning contexts and creates new opportunities for promoting optimal learning processes, with a particular emphasis on student agency. This article reviews two dimensions of student agency that emerged in this study: (a) synergy between scaffolds; and (b) self-orientation and assuming ownership/responsibility for the learning process.

7.1. Synergistic Effect between Three Key Scaffolds

The research findings indicate varying prevalence of scaffold use across cognitive, emotional, and social learning contexts. The most frequently used scaffolds were: consultations with course lecturers, the digital textbook for learning Scratch, and interactions with course peers. These scaffolds appeared to intensify one another, thereby enhancing the learning process. The relationships among them were synergistic, as they provided support simultaneously for the same need-coping with challenges in the process of game design. The lecturers' frequent use of meta-scaffolding within the environment further encouraged this synergistic effect. In line with Herrenkohl and Wertsch [7] the synergy between these scaffolds fostered relationships of mastery, rather than mere appropriation. Because these scaffolds were perceived as legitimate, logical, and essential, and were frequently used, they promoted independent thinking [34].

However, the findings also showed that not all tools facilitated learning to the same extent. For example, the WhatsApp group was not used, and lesson recordings were used relatively infrequently. These scaffolds may have been less attractive compared to others, serving as "redundant scaffolds" [14]-that is, supports directed at the same need but at different times, and thus less appealing during the main phase of project work.

7.2. Manifestations of Self-Direction and Ownership of Learning

In this study, the scaffold-rich learning environment encouraged both autonomy and the delegation of responsibility to learners. Grabinger and Dunlap [35] discuss the potential of such environments, noting that they: "evolve from and are consistent with constructivist philosophies and theories; promote study and investigation within authentic (i.e., realistic, meaningful, relevant, complex, and information-rich) contexts; encourage the growth of student responsibility, initiative, decision-making, and intentional learning; cultivate an atmosphere of knowledge-building learning communities that utilize collaborative learning among students and teachers; utilize dynamic, interdisciplinary, generative learning activities that promote high-level thinking processes (i.e., analysis, synthesis, problem-solving, experimentation, creativity, and examination of topics from multiple perspectives) to help students integrate new knowledge with old knowledge and thereby create rich and complex knowledge structures; and assess student progress in content and learning-to-learn through realistic tasks and performances" (p. 10).

The development of responsibility for learning manifested itself on several levels, beginning with the choice of learning methods, distributed scaffolds, type of game, and content area. While the final product was pre-defined, the path to achieving it was left to the learners' discretion. The availability of multiple scaffolds enabled PSTs to prioritize what was most convenient and effective for them. Furthermore, this freedom of choice encouraged them to add their own scaffolds to the environment, seek external support, or consult online resources.

These findings illustrate two key concepts from the empirical literature regarding the learner's role in the learning process: student agency and self-determined learning. Student agency (SA) and self-determined learning (SDL) both emphasize personal motivation and autonomy. These approaches give individuals the freedom and resources to direct their own learning according to their interests, goals, and values. They recognize that learners have unique needs and abilities, and seek to foster intrinsic motivation and a sense of ownership over one's learning [9, 10]. Research has shown that this approach leads to positive outcomes, including increased motivation and engagement, improved academic performance, enhanced psychological well-being, and the development of lifelong learning skills.

The findings of this study indicate three positive outcomes: increased motivation, greater engagement, and enhanced lifelong learning skills. The implications for teacher educators are that PSTs should be encouraged to engage with unfamiliar areas, such as Scratch programming. The goal is to present learners with meaningful challenges that foster student agency and self-determined learning. This requires building relationships of trust between lecturers and PSTs, creating an environment that supports autonomy, and establishing clear expectations for the final product. As this type of study involves researcher participation and agenda, the limitations of the findings should be acknowledged, balancing context specificity with attempts at broader generalization [32].

The implications of this study for teacher educators are that PSTs should be encouraged to practice areas that are not necessarily familiar to them, e.g., the Scratch software. The aim is to set a meaningful challenge to the learners, making them develop student agency and self-determined learning. This requires relationships of trust between the lecturer and the PSTs, as well as a space that facilitates autonomy and clear expectations for a product. Since this type of study includes involvement of the researchers and their agenda, the limitations of the findings should be maintained beyond the context in which the study has been conducted, trying to find the delicate balance between sticking to the context and the attempt of petite generalization [32].

While the scaffolds offered in the environment are generally generic, their use may be unique to Scratch; in other environments, different patterns of scaffold use may emerge. Therefore, it is recommended to conduct further studies with larger groups of PSTs, in varied contexts and content areas, for comparison. Additionally, future research should explore gender and disciplinary aspects related to PSTs' self-efficacy in learning Scratch.

In conclusion, this study suggests that creating a learning environment characterized by diverse digital spaces, autonomy, and a variety of scaffolds stimulates PSTs' ownership of their learning and promotes independent learners. Such an environment redefines the lecturer's role as an emotional supporter and source of motivation. The scientific contribution of this study lies in developing distance learning models that enhance personal and autonomous self-determined learning, even in academic settings.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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