LEARNING AND TEACHING COMPUTATIONAL THINKING: A CROSS-DISCIPLINARY, COLLABORATIVE, USER-CENTERED DESIGN MODEL

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ABSTRACT

The paper shares the results of the process of forming a cross-disciplinary collaborative team and using a user-centered design framework to co-create a self-directed, self-paced, personalized, flexible learning environment as an alternative approach to preparing PK-8 preservice teachers to teach computational thinking. It is part of a larger project that attempts to respond to the need to create a computer science curriculum within a credentialing learning environment.

KEYWORDS

Computational Thinking, Collaborative Design Model, User-Centered Design, Computer Science and PK-8 Preservice Teachers, Alternative Pathway

1. INTRODUCTION

Despite efforts to underscore the need for computing and computational thinking skills for all students and demonstrated evidence that computational thinking (CT) and computer science (CS) should be introduced in earlier grades and embedded throughout the school experience (e.g., Wurman & Donovan, 2020), CT/CS in PK-8 teacher education programs remains inconsistent and, in many cases, non-existent (Code.org, 2020). There is a lack of teacher certification programs preparing PK-8 teachers with a deeper knowledge of CS concepts and capabilities. Initial training opportunities in colleges of education are scarce. Even though there are professional development (PD) opportunities for in-service teachers, preservice teachers do not benefit from these opportunities due to their lack of experience and practical knowledge. Despite national efforts, there is still a lack of well-constructed, high-quality CT/CS preparation programs for PK-8 preservice teacher candidates (PTCs). PK-8 teacher preparation programs in the U.S. find it challenging to incorporate an add-on quality CS certification program due to 1) a lack of PTCs' interest and understanding of CS (Google/Gallup, 2020), 2) little room for adding coursework to existing teacher education programs, and 3) challenges training faculty to teach CT/CS concepts and courses. Thus, CT/CS education advocates have recommended that education systems initiate alternative pathways and improve them over time (Code.org, 2018).

1.1 The Purpose of the Study

The paper shares the results of forming a cross-disciplinary collaborative team and using a user-centered design framework to co-create a *self-directed, flexible, and open learning* (SDFOL) environment as an alternative approach to preparing PK-8 PTCs to teach CT. It is part of a larger project that attempts to respond to the challenges mentioned above by creating a curriculum for CS within a credentialing learning environment. It further applies the literature review results in conceptualizing a co-design framework to develop a pilot SDFOL module on CT for the learner-managed CS credentialing learning environment. The module aimed to transform the teaching and learning process from a course-based, instructor-guided approach to the SDFOL model.

1.2 Cross-Disciplinary Collaborative Design Team

A cross-disciplinary partnership was formed to exchange and share expertise, ideas, resources, and responsibilities throughout the design and development process. It was to provide opportunities for the team members to learn from each other while designing and reflecting on the intentions and implications of the initiative and improving their knowledge and skills of the CS/CT. The cross-disciplinary partners consisted of two computer science experts, five PK-8 teacher educators, three instructional/learning design experts, two instructional developers, and four diverse PTCs. Also, an advisory board comprised of community members' representatives was formed to advise and review various project phases.

2. COLLABORATIVE AND USER-CENTERED DESIGN: A REVIEW OF THE LITERATURE

S*elf-directed learning* (SDL) originated in andragogy or adult education (Knowles, 1975). According to Knowles (1989), *SDL* is an environment in which learners take the initiative with or without the help of others, assess their learning needs, formulate goals, implement appropriate learning strategies, and evaluate their learning outcomes. As an instructional method, *SDL* refers to independent learning in which the learning materials are designed and developed in advance, predicting that learners take the primary responsibility for planning, carrying out, monitoring, evaluating, and reflecting on their learning (Pintrich, 2004). The adult education literature points to promoting motivation, metacognition, and self-regulation as the most important benefits of self-directed learning (e.g., Knowles, 1975; Brockett & Hiemstra, 1991; Gibbons, 2002; Long, 2000). Studies show that SDL correlates with students' academic performance and is a good indicator of academic achievement in the traditional classroom (e.g., Cazan and Schiopca, 2013; Khiat, 2015; Malison, 2018; Tekkol & Demiral, 2018).

Web-based, open, and flexible learning provides the necessary components for creating an engaging SDL environment. In a web-based, computer-mediated self-directed learning environment, instructional materials are prepared in advance of the instructional events (Keller, 2010), including instructional and motivational strategies at the time of development based on predictions of learner motivation, interest, attitude, abilities, entry knowledge, and skills. Based on the literature, SDFOL can be conceptualized as an environment that offers four specific conditions for learning: 1) enhancing motivation by incorporating interest-based learning, 2) providing flexibility to encourage control of pace, time, and flow of learning, 3) offering an open learning environment to allow the learner to choose what to learn and how to learn and what resources to use, and 4) promoting metacognition by encouraging self-determination, self-control, and self-regulation throughout the learning process.

2.1 Design Framework

SDFOL was used as the general design framework. The framework offers the learners control and authority over their learning. It is free from the limitations of time, place, and pace of learning. The flexibility further includes choices regarding the entry and exit points and the selection of learning activities to meet learners' needs, communication methods, assessment tasks, and educational resources. The SDFOL aims to make learners more self-determined and independent as a learner-centered pedagogy and describes the teachers as designers of the learning environment and learning facilitators. SDFOL empowers learners and teachers to extend learning opportunities beyond traditional learning environments by bridging formal and informal learning experiences through the effective use of technology and resources. Digital learning modalities combined with performance-based progressions make it possible to meet each student's unique needs (iNACOL, 2016).

Moreover, interest-driven learning is used as a motivator for learning activities. The benefits of interest-driven learning as a motivator for learning activities are associated with the learner's perception that specific knowledge or skills help pursue an interest (a mastery goal). It is also connected with more effort and persisting longer at the tasks. Self-determination theory demonstrates that intrinsic motivation leading to persistence cannot emerge unless a person has a sense of autonomy (Ryan & Deci, 2006). Interest-driven learning emphasizes motivating and sustaining learner interest by offering relevant real-world tasks and creating a conversational, reflective, and innovative learning space (Spector, 2014). Culture and context are addressed through interest-driven learning through meaningful, authentic, culturally relevant environments and an opportunity to self-assess and reflect on applying the knowledge to solve problems.

2.1.1 Iterative Collaborative Design Process and Study of its Impact

Developmental/Design-based research was used to study the collaborative design and development process and its impact on the quality of the products and the team's knowledge, skills, and attitude. The following questions guided the study.

1. What process did the collaborative team use to design and develop the pilot module on computational thinking?
2. What was the result of the learner analysis, and how did the team use the results?
3. What were the effects of the collaborative design and development approach on the team members' knowledge, skills, and attitude toward integrating CT in their teacher education courses?
4. What impact did the collaborative design process have on the quality of products?
5. What evidence suggests that the module's design framework, design specifications, and delivery strategy were effective as an alternative model to preparing PK-8 TCs to teach CT?

2.1.2 Data Collection and Data Sources

Both quantitative and qualitative data were collected.

- Collaborative team meetings minutes and discussions
- Collaborative team members' deliverables and products
- Open-ended self-reflection questionnaires for collaborative team members
- Teacher education candidates survey, review protocol, and interviews
- Student personas developed by teacher education faculty
- Observation of the team members' discussion and collaboration (conducted by one team member)

The data collection is still underway. The iterative process of collecting and analyzing data has been informing the revisions and modifications and ensuring ongoing progress toward achieving the goals and objectives of creating the learning materials. Formative elements of the review have been continuous, reflective, and responsive. They allowed examining the challenges of preparing a CT module, adopting targeted pedagogies, developing interactive, personalized self-directed learning materials, and enhancing the collaborative teams' knowledge, skills, and attitude.

3. INITIAL RESULTS

Q 1. Throughout the co-design process, team members spent quality time discussing and learning from each other with different backgrounds and CS knowledge. As the team developed a better understanding of the CS curriculum and CT concepts, it focused on analyzing learners and identifying salient characteristics of preservice teachers, particularly their interests, background knowledge, and pedagogical, socio-economic, and ethnic backgrounds. The next step centered on developing a curriculum map for CS, creating the design specifications and guidelines for elements of the curriculum, focusing on decomposing CT concepts, and developing templates for its lessons. Once the template for the design of the CT concepts was developed, the team spent an iterative process creating storyboards and prototypes.

Table 1. Q 2. Collaborative team members responded to a series of open-ended questions

Questions	Key Findings
In your opinion, how well is the team progressing toward its goal?	"I think we are making good progress" "Content design is moving along, and we have some plans for other aspects of the project. I think there are still areas that will need to do extensive work on, specifically the personalization and assessment areas."
What aspects of our meetings do you find most helpful?	"Working in the meeting time rather than outside the meetings whenever possible." "Discussion of specific items," "The ideas and perspectives from the rest of the team."
Is there anything you would like to change about our planning meetings?	"I am not sure we need to review everything in every meeting. I feel like it is taking away much time from executing," "I have had a hard time wrapping my head around the final version without an example. . ."
Is the planning and team meeting process a good learning experience for you?	"I learn more and more about CT and the CS/Coding world every time we meet. I have a fairly decent understanding of CT, but the CS/Coding information that has been discussed in our planning of the modules is totally new for me," "Yes. It is great to learn about the norms in education outside of a CS context. Many CS educators are not trained as educators," "It's helpful to discuss concepts and analyze examples."
How do planning meetings compare to a workshop to learn about CT?	"We are not learning information THEN doing; we are doing and learning information BY doing." "This is more focused and personalized." "Our project leads us through the discovery process with input from multiple perspectives rather than a workshop that has an

	intended, guided path towards understanding." "Our project leads us through the discovery process with input from multiple perspectives rather than a workshop that has an intended, guided, path towards understanding."
Have planning meetings helped you potentially integrate CT into your courses for teacher education students?	"Yes - it inspires me to continue down a research path that I have already set out on." "Not as of yet, but I suspect it will. Even defining what we mean by each of the skills in CT will allow me to make them explicit in the classroom." "Yes. Being on this team helped me to think about the Computational Thinking background knowledge and hands-on experiences."

Q 3. PTCs' responses to a survey asking questions about their backgrounds, experiences with CT, and learning preferences showed that most respondents recognized the value of CT concepts. However, some did not understand how to incorporate concepts into the curriculum or teach it in their classrooms. There seems to be a disconnect between associating and actualizing CT concepts (in name and/or definition) with the corresponding pedagogical skills. Visual (88 of 93 students), hands-on (83 of 95 students), and self-paced pedagogies (85 of 95 students) were listed as the most favorable learning preferences. Reading written text was the least favorable learning preference. Only about half of the participants knew about and/or had taken coursework on CT (56.6% and 43.86%) or believed they used it (51.42%), but most thought it helped solve problems (68.58%). PTCs showed an interest in CS, finding it interesting. They believed it was important for their students to learn (>80%) and maybe even more important for underrepresented students (88.66%). Most participants preferred visual information (94.63%) that they could apply with hands-on activities to learn (87.37%) and were curious about the mechanisms that make things work (82.11%). Most believed that CT is helpful outside of CS (92.63%) but lacked confidence in their knowledge and ability to implement CT in their teaching without additional instruction (77.45% and 81.06%). Data related to questions 4 and 5 are under analysis and will be reported at the CELDA presentation.

4. SIGNIFICANCE

The SDFOL module on CT for PK-8 teachers has a high potential to be scaled at the state and national levels. A well-designed module provides pilot evidence to use the credentialing pathway as a model for preparing teachers to teach CS. The study's results provide evidence of the advantages and challenges of the collaborative design approach. They further show the impact of the rigorous, research-supported, flexible learning environment on empowering PK-8 PTCs and their CT competencies. It offers evidence of whether this transformative approach will increase teacher candidates' confidence and motivation in teaching CT and whether it will be a good model to motivate PK-8 PTCs to teach CS. It will also show if the collaborative design can serve as an innovative PD approach for education faculty.

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