Exploring Andragogy Principles for Broadening Participation in Computing Education for Lifelong Learners

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Abstract

Computing education could foster older adults' cognitive abilities and create a community of active lifelong learners. However, older adults are under-represented in computing education. This study examined how to design strategies to broaden participation in computing education for older adults based on andragogy principles. Two case studies focusing on computational thinking plugged and unplugged interventions were designed. The study recruited thirty-four older adults (age 60+). The structural thematic analysis was employed to analyze the qualitative data. The findings of this study revealed that computational thinking unplugged approaches substantially improve older adults' social lives through collaborative learning, and supported their self-regulated learning experiences compared to plugged approaches. Regarding their cognitive improvement, computational thinking plugged activities were shown to impact older adults more, which can spark their interest in computing education. This study contributes to broadening participation in computing education literature by discussing the implications for exploring adult-focused learning principles and strategies.

CCS Concepts

• **Social and professional topics → Adult education**.

Keywords

Broadening participation in Computing, Lifelong learning, Adult education, Andragogy principles, Computational thinking

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1 INTRODUCTION

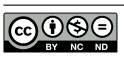
Continuous learning in an advancing world of science and technology remains relevant for the development and sustainability of any society. Nowadays, adult education, especially in a non-formal setting, is gaining popularity across the world even though it has existed since the 18th century. One of the goals of the United Nations Educational, Scientific and Cultural Organization (UNESCO) is to develop citizenship education where learning can take place from cradle to grave. Recent advances in science and technology have created the need to foster lifelong learning among older adults. Besides, the population of older adults – prone to several challenges due to aging – is growing worldwide, including in developed nations, which necessitates ways to support their social and mental well-being.

Studies have shown that computing education has the potential to support older adults by stimulating their brains and keeping them digitally active [2, 24, 28]. Meanwhile, computing education has been traditionally concentrated in formal settings such as K-12 and colleges [12, 26]. Moreover, recent studies have shown that older adults are motivated to learn computer programming [1, 18]. However, these older adults learn differently than younger learners. For example, Guo [18] found that adults perceive frustration and cognitive decline when they encounter difficult programming problems. This finding suggests that certain pedagogical approaches, such as problem-based learning, may not be suitable for adult learners. Hence, a more learner-centered approach is desirable to foster computing education for older adults (also referred in this article as lifelong learners).

Early scholars and adult educators have introduced andragogy as a suitable approach for fostering adult education [25]. Andragogy is a theory of adult learning that has been popularized by Malcolm Knowles [22] with core principles for developing strategies, resources, and environments to enhance adults' learning experience. Deploying computing education for adults using the andragogy principles could boost their cognition and programming skills. However, this approach has been underutilized in computing education, particularly for adults.

To broaden participation in computing education for adults, this article aims to conduct a pilot study to explore how plugged and unplugged computational thinking (CT) exercises grounded in andragogy principles could foster computing education for lifelong learners [35]. The study engaged older adult learners in Oregon to teach them the basics of computing and exposed them to coding in a fun way using online block-based coding environments - Scratch - to solve computational problems. The study utilized a workshop approach that allowed the participants to engage and collaboratively co-design activities that could stimulate their cognitive thinking and computational abilities. The limited exposure offered by this workshop may not be enough to produce a "programmer" but could spark their interest, stimulate their brain, and motivate them to

*Both authors contributed to this research.



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develop new skills. Therefore, the following research questions are formulated to guide this pilot study.

RQ1. *How can we explore andragogy principles to broaden participation in computing education for adults using computational thinking activities?*

RQ2. *What are the learning outcomes for engaging adults in computing education using computational thinking plugged and unplugged activities?*

2 THEORETICAL BACKGROUND

2.1 Lifelong learning and Andragogy Principles

Lifelong learning is the self-motivated pursuit of growing knowledge for personal or professional reasons, and grows people's social circles and personal development [19]. This lifelong learning, as well as adult learning, requires unique strategies to be effective.

Malcolm Knowles [22] is a key figure in developing adult education systems and models. He introduced the term andragogy as a suitable approach for developing adult learning processes [22]. Knowles splits this up into five main principles: *self-concept* (from dependence to self-direction), *experience* (using past knowledge), *readiness to learn* (real-life applicability), *orientation to learning* (problem-solving focus), and *motivation* (driven by internal factors) [21]. These principles are important today, where adaptation is necessary to stay relevant in our vast changing environment.

Lifelong learning will be essential for personal fulfillment, employability, and an active lifestyle. We also see five main principles for lifelong learning: *inclusivity*, keeping it accessible for all regardless of age or social status; *flexibility* with times and places of learning [13]; *recognizing prior learning*, acknowledging and valuing prior skills and knowledge through informal and nonformal learning contexts; *learner-centered approach*, meeting the needs and preferences of learners; and *integration with life*, staying practical with immediate relevance to the learner's personal or professional life [19].

These key principles of andragogy and lifelong learning can be leveraged to create a learning environment which fosters respect and uses adult learners' experiences to align with their current motivations, to keep them mentally active and up to date with current technology. Online-based coding environments such as the Scratch are good environments to uphold this. These environments give an engaging way to introduce computational thinking, helping learners see the relevance of their learning. Computational thinking refers to thought processes formulated or deployed for problem-solving using computational steps [7]. Being popularized by Jeannette Wing [33], computational thinking education has shown impact on K-12 [17] and college learners [4], yet underexplored in adult education context [1, 35]. Further, workshops where participants co-design activities promote inclusivity and flexibility, tailoring the learning environment to participants' needs, enhancing motivation and engagement [13]. Integrating lifelong learning and andragogy principles into computing education for adults can give them a supportive, engaging, and effective learning environment. This will help to broaden their participation in computing and ensure that learning is relevant and meaningful for adult learners [1, 19].

2.2 Computing education for lifelong learners

As technology grows, it is harder for adult learners to keep up with the moving things around them, and learning techniques move further away from hands-on learning. As the digital age continues to grow, the demand for skills within computing and the standard level of computing knowledge grows. Lifelong learners must stay engaged with these skills to remain mentally active and keep competitiveness within their lives. Collaborative learning environments and workshops are useful ways to foster a supportive learning environment, especially within computing education for older adults [29]. These allow participants to share previous experiences and knowledge to support each other's ideas, creating an environment that directly aligns with the principles of lifelong learning. Additionally, these environments are flexible, inclusive, and tailored around adults' backgrounds and needs, allowing workshops to be successful [27].

Recent studies have shown the relevance of broadening participation in computing education for adults [2, 5, 18, 28]. While programming education in K-12 and colleges are the mainstream with many innovative approaches nowadays, developing curriculum to foster computational thinking, problem-solving skills, and programming education for lifelong learners has enormous benefits in building inclusive community [18] but yet to be adequately researched as shown in a recent study [5]. Moreover, a few scholars have explored this domain and have reported potential benefits as well as challenges in introducing older learners to programming. For example, Guo [18] reported that older adults (over 60 years) perceive programming to decline their cognitive capabilities due to how difficult it is to comprehend. The same author reported that older adults are motivated to learn programming because it can keep their brain challenged and active as they age. Additionally, it was also found that most older adults who could not find the opportunity to learn programming during their active working years would like to make up for the loss of youthful opportunities.

Earlier, Nycyk and Redsell [27] developed an innovative approach that could foster adults' motivation to persistently learn computing using what they termed "computer tuition practice", which essentially relates to excellent tutors' teaching styles and smooth relationships they build with adult learners. The authors argued that unique qualities of tutorship can motivate adults to develop a positive attitude to computing education. In addition, Ohashi et al., [28] developed circles of curriculum to teach older adults programming using computational thinking activities and Scratch programming language. They later strengthened adults' programming education by converting some older adults who have received advanced training and are knowledgeable enough into instructors to make the program sustainable. Their study shows that applying multifaceted approaches to developing a curriculum for adult programming education could motivate their learning and could provide opportunities for sustaining lifelong learning.

Looking past the clear benefits of democratizing computing education [6], several barriers can halt computing education for adults. For example, financial limitations, time contractions, and lack of motivation and confidence are common issues in teaching and learning new technology for adults [5, 18]. To overcome these barriers, education programs must contextualize learning strategies, and

develop process that support flexibility with access to technology and an adaptive learning environment, allowing adults to have enhanced learning experiences, as well as the opportunity to expand on the information after the learning sessions to learn on their own [14]. Identifying and solving these barriers requires a more multifaceted approach as it requires integrating technological, pedagogical, and social strategies. For example, having flexible scheduling and ease of access to technology reduces the stress of time and cost. Also, learning in a social environment with peer support can help boost the learners' confidence by taking the pressure of isolation and lack of confidence.

3 POSITIONALITY STATEMENT

As researchers investigating the landscape of computing education for older adults, we recognize the importance of articulating our individual and collective positionalities. Our perspectives are shaped by our experiences within the fields of computing education, educational technology, and our geographical location on the West Coast of the USA, a region experiencing rapid growth in its older adult population. The first author brings over six years of research experience in computing education and educational technology. This work has primarily focused on older populations, a recent interest developed by the first author in addressing the underrepresentation of older adults (60+) in computer science education. The second author, a mentee of the first author, is a student with a strong interest in CS education and lifelong learning, and their involvement is guided by a commitment to exploring accessible and inclusive learning environments for all ages.

Our positionality also considers our potential biases and assumptions. We acknowledge that our relatively young age compared to the population we are studying may lead to certain preconceptions regarding the technological skills, learning styles, and motivations of older adults. Furthermore, while we believe in the potential of computing education to empower and enrich the lives of older adults, we recognize the need to avoid imposing our own values or overlooking the diverse needs and preferences within this demographic. To mitigate these biases, we commit to engaging in reflexive practices throughout our research, actively seeking the input of older adults themselves, and critically examining our interpretations of the data we collect through the lens of established theories in adult learning and inclusive design.

4 METHODOLOGY

In this research, two pilot cases were conducted. The first case study consisted of computational thinking for adult lifelong learners using an unplugged approach. The second case study consisted of introducing lifelong learners to programming using the plugged approach.

4.1 Context and Participants

This study was conducted with members of the Institute of Continuous Learning (ICL) at a liberal arts university in the Pacific West of the United States. The ICL is a community of lifelong learners whose members are retirees with ages mainly above 60 years and are from diverse fields of life including medicine, geology, and education. The institution has over 70 members and meets in their center for learning from Monday through Thursday weekly. Their goal is to learn a variety of topics that can stimulate their brain and keep them active while they are aging. In total, 34 older adults participated in this study (consisting of the two case studies). While there were over 50 persons who attended the lecture delivered in the first case study held during spring 2024, only 30 actively participated in the unplugged activities deployed in that session. Following the first case study, we recruited 14 adults who partook in the first study to also participate in a summer workshop meant to introduce older adults to programming using a plugged approach (second case study). Out of the 14 persons that signed up only 4 adults made it to our final activities in the workshop. The remaining 10 adults could not make it due to several reasons which they communicated to the authors prior to the workshop date.

Regarding ethical consideration, this research obtained an approval from the authors' Institution Research Board (IRB). In addition, the participants were informed that participation in this research is voluntary and they have the right to withdraw from participating at any time without any prejudice. Each participant read the IRB approved consent statement and agreed by appending their name as signature.

4.2 Study design

This qualitative research was designed and conducted in two case studies with the first case study linked to the second. While the first case study was designed to focus on computational thinking activities (unplugged) to foster sets of skills that empower older adults with foundations to learn how to program, the second case study was meant to allow them delve into actual learning of programming using plugged activities of block-based and text-based programming languages (see Figure 1). In the next two sections, we provide a detailed description of the lesson design, framing of the curriculum, and learning objectives that align with the andragogy principle.

4.3 Case Study 1:

This study took a lecture approach where the authors used PowerPoint presentation to teach older adults what is and is not computational thinking, its definition, concepts and principles. Then, we introduced the concept of unplugged activities demonstrating computational thinking scenarios adapted from the Bebras Computing Challenge[1]. The rationale for selecting Bebras problems, originally designed for K-12 computational thinking, for use in a study with older adults is grounded in their proven ability to assess and cultivate core computational thinking skills-such as algorithmic reasoning, data representation, and problem decomposition-in a manner that does not require prior technical background, making them accessible to diverse populations [3, 4, 11]. Although we acknowledge that contextualizing problems to better reflect the life experiences and interests of older adults could enhance engagement and relevance, the current use of standard Bebras challenge problems provides a validated and widely available assessment framework; adapting or developing context-specific problems for older adults remains an important direction for future research efforts.

[1] https://www.bebraschallenge.org/

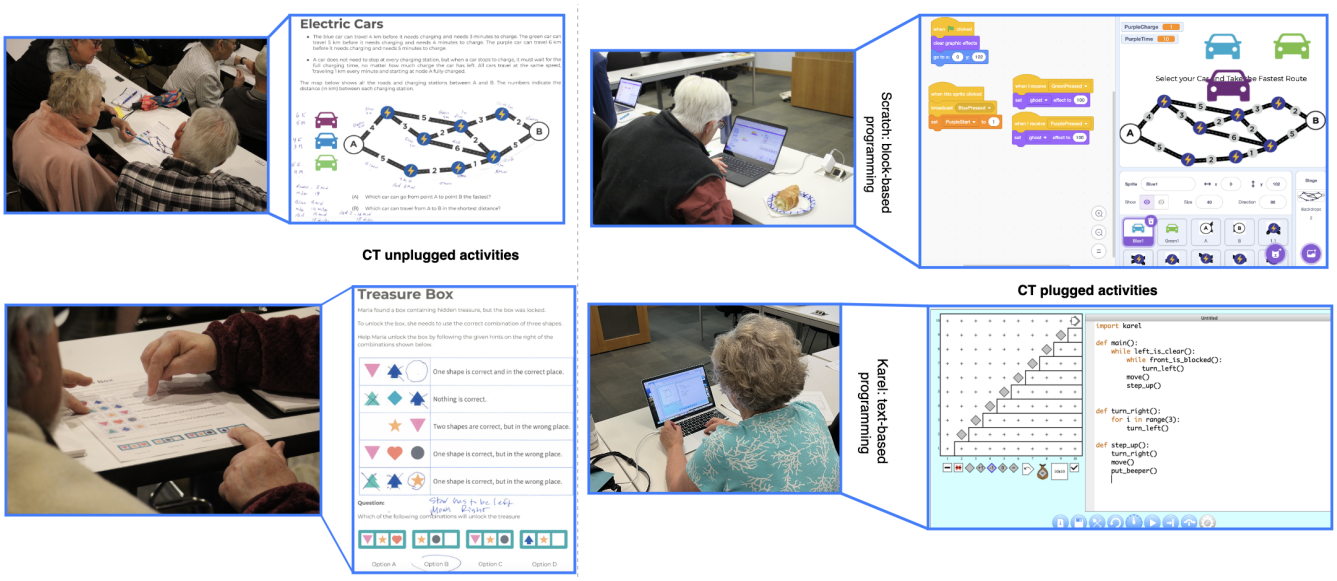

Figure 1: Images showing participants engaging with the plugged and unplugged activities during the study

The entire duration for this session was 3 hours. The main learning objectives in this lecture were to introduce older adults to problem-solving strategies using the computational thinking concepts such as pattern recognition, abstraction, decomposition and algorithmic thinking. The first session of the lecture introduced De Bono's six-thinking hats [16] as general strategy to demonstrate problem-solving skills. The authors then engaged the older adults to use these same De Bono's thinking hats to unravel a computational thinking problem (Tower of blocks puzzle which presents an optimization problem related to stack and queue algorithms in data structure and requires critical thinking to unravel).

Furthermore, two other computational thinking problems (electric cars and treasure box puzzles) were introduced in the second phase of the session. Adults solved these problems in pair-groups consisting of two persons minimum and four persons maximum. After ten minutes of collaboration, each group takes turns to present their solution and explanation of their thought processes. We documented their explanation by recording the audio and retrieved their paper containing the puzzle where they also scribbled on. This first case study session ended with an announcement to enroll for a planned summer workshop to introduce older adults to programming using plugged approaches of block-based and text-based programming languages.

4.4 Case Study 2:

The second study was a workshop to pilot computing education for lifelong learners (CS4Life) which took place after six weeks following the first study. The goal of the CS4Life workshop is to make computing education accessible to older adults. Through a fun and engaging workshop, authors believe that older adults will learn the basics of programming using block-based coding language such as Scratch and text-based coding language such as Python. They are to learn in collaboration to co-design activities to boost your cognitive and computational thinking skills. Thus, at the end of this workshop, older adults were expected to achieve the following learning objectives: (1) Understand characteristics of an algorithm and design of algorithms to solve familiar computational thinking problems (2) Formulate and unravel problems using decomposition technique (3) Gain basic knowledge on programming constructs, variables, assignments, expressions, conditions, functional programming, loops, and debugging skills, and how to use them to solve simple problems (4) Explore block-based programming using Scratch and write simple text-based Python codes.

The workshop recruited participants from the members of ICL who participated in the first case study and are still interested in piloting the next phase of the study designed to be a plugged approach.

4.5 Data collection

In case study 1, the main data collection methods were observations, audio recording of the session, and participants' scribbled notes. Due to the contextualization of the learning resources for older adults, the authors feel that this data collection method is suitable for the first case study. In case study 2, the authors collected data using multiple sources. For example, surveys adapted from empirically validated instruments that evaluated adults' achievement in an intervention and aligned with andragogy principles [34]. Samples of survey questions include: *What are you expecting to learn in this workshop? What have you learned and how would this workshop have real-world effects on your life? What motivates you to learn computing and programming in this workshop?* In addition to the survey, data was collected by recording the collaborative session and open discussions. The survey questions and other anonymized data collected and analyzed in this study are available on request from the authors.

4.6 Data analysis

This study employed a qualitative method and followed the process of inductive content analysis to examine the data to address the research goals. Inductive content analysis is suitable for gaining insights especially when little to nothing is known about the data [30]. In doing this, the authors first designed a protocol for data analysis based on Structured Tabular Thematic Analysis (ST-TA) introduced by Robinson [31]. ST-TA provides a structural approach for analyzing qualitative data with an in-depth interpretive understanding of small text data [31]. According to the ST-TA guidelines, preliminary themes may exist upon which codes emanating from the text data could be developed. Moreover, in this study, the authors identified themes to align with the principles of andragogy and computational practices. A meeting was held among the authors to discuss themes and consensus was reached which includes the five principles of andragogy outlined by knowles and aspects of computational thinking concepts or practices (see Table 1).

Table 1: Analysis of codes based on andragogy principles and CT practices: Coded data of unplugged activities (frequency of code N=33) and plugged activities (frequency of codes N=120)

Andragogy principle	UA	PA	CT Practices	UA	PA
Motivation	3.0%	10.8%	Abstraction	21.1%	7.5%
Experience	12.1%	5.8%	Decomposition	3.0%	8.3%
Self-directed learning	18.2%	8.3%	Debugging	3.0%	19.2%
Readiness to learn	-	5.8%	Pattern recognition	-	1.7%
Orientation to learn	-	5.0%	Generalization	-	1.7%
			Collaboration	24.2%	8.3%
			Algorithmic thinking	6.1%	3.3%
			Reverse engineering	6.1%	-
			Simulation	3.0%	-

Note: Unplugged Activities (UA); Plugged Activities (PA)

5 RESULTS

This section presents the findings to address the research questions formulated for this study.

RQ1. *How can we explore andragogy principles to broaden participation in computing education for adults using computational thinking activities?*

To provide insights into how andragogy principles and computational thinking approaches can be explored to broaden participation of computing for adults, this study separately analyzed the plugged and unplugged activities deployed in the two studies and presents its findings in Table 1. The coded comments from the unplugged activities (N=33) shows that older adults applied their prior experiences in unraveling the problem as shown in their use of the concept of abstraction; demonstrating high levels of collaboration; and the activities appear to foster their self-directed learning. For example, some of their comments that suggest use of experience includes: *"I'm a language teacher and work a lot with integrity and distinctly and we got option B very quickly by . . . "*; *"So we followed a very similar exclusionary process, we came up with option B."*

Regarding their collaboration and self-directed learning, the following statements revealed how older adults demonstrated this characteristics: *"... looking at it from this way but we both came to the same conclusion and I'm not sure how she got to this conclusion."*; *"We followed the routes and we thought by analyzing all of that, the green car was the fastest and then we also did the same thing for the other cars and what route they had to take and how many stops they had to make and we thought the green car was also the shortest distance for that."*

However, the older adults were not very motivated with the unplugged activities. They also did not seem to show any characteristics of andragogy principles of *readiness to learn* and *orientation to learning*, which explains why they were not very motivated.

Regarding the plugged activities, the analysis in Table 1 shows that older adults exhibit high levels of motivation (10.8%) compared to the unplugged activities (3.0%). In addition, they also demonstrated characteristics of readiness to learn and orientation to learn which were both absent during the unplugged activities. This suggests that older adults' interest in computing education can be sustained with plugged activities and they are fascinated with learning programming. For example, one of the participants asserted: *"So now I'm gonna go home and code for hours!"*. Similarly, another participant expressed thus: *"I have these word games to try to keep my mind active but this to me was more intriguing and if I had a booklet of these problems and then I could go in and try to solve them then this is what's going to get my mind active."*

Moreover, the plugged activities appear to have limited impact on older adults' self-directed learning compared to the unplugged activities. They also employed less experience on plugged activities, which means that learning of coding is fairly new to the majority of the participants. Furthermore, the older adults demonstrated more debugging skills in plugged activities (19.2%) compared to the unplugged activities (3.0%). Although less collaboration took place during the plugged activities (8.3%) unlike the unplugged activities (24.2%).

In addition, the analysis found two other themes that did not align with the andragogy principles or CT practices but are very relevant to adult learning processes – self-confidence and frustration. The substantial percentage of comments (7.5%) from older adults while engaged in plugged activities were found to show that they gained self-confidence. Meanwhile, they also expressed frustration (6.7%) emanating from engaging in the plugged activities.

RQ2. *What are the learning outcomes for engaging adults in computing education using computational thinking plugged and unplugged activities?*

To address this research question, we analyzed the data gathered during the in-person session and survey responses that contained participants' self reported experiences. We present the findings based on the themes below.

Memory retention: Before commencing the workshop (case study 2), we asked the participants to solve the same puzzle they had collaboratively unraveled in the first study. The goal here is

to examine their memory retention ability. The period between the first and second studies was six weeks. We found that 75% of the older adults who participated in the second study were able to independently solve the puzzle, indicating high memory retention ability.

Cognitive impact: The analysis of self-reported survey indicates that the plugged activities stimulate older adults' brain and positively impacted their cognitive functions. Examples of their responses read thus: *"It has made me realize that simple coding exercises are important for increasing cognitive function." "I have new tools to really challenge my brain and help build new neurons." "I now have multiple platforms to work on for coding exercises which will help keep my brain active."*

Intrinsic motivation and interest in computing: Although programming can be challenging, older adults found the approach used (from unplugged puzzles to text-base coding of a robot) to be motivating. They are challenged to continue to learn coding. Examples of the responses includes: *"I love puzzles, and this was new to me after not coding for 40 years! It was challenging and fun." "To continue to work more difficult problems and possibly learn different coding languages." "I felt good about learning the simple coding in Karel and the glimpse into loops, etc., to make more complex problems."* Additionally, they found computing to be fun and wish they have more opportunity to learn together. *"I always like to learn new things and this was interesting and fun." "It would be fun to have periodic get together in a computer lab to try scenarios others have set up and try to work them out."*

Social well-being: The participants reported that the activities supported their social well being through active collaboration with other folks. For example, they expressed the following: *"It is challenging and fun and more advanced than playing games on my phone to try and keep myself sharp." ... fun exercises in coding would be even better to increase brain activity. If done in a social setting, it would be good collaborative event."*

Self-confidence: The participants gained confidence from engaging in problem-solving and coding, which is an important gains for older adults in that age. For example, some of them asserts: *"I was able to share my experience and my own design with others who are interested in it now, too." "I learned a lot in the classes and was able to use that and the Chapter readings to work on the problem and create my own programs." "My daughter got her masters here in business and now works at Boeing Now I'm gonna tell her, look what I can do."*

Learning experience: The participants' reflection on the intervention indicates that they gained enhanced learning experience. *"I realize now that I am pretty good at using common programs for home computing, but not at all knowledgeable about coding. So It was a great experience to learn something new." "This workshop was well set up and we were given all the tools and support we needed to succeed and continue to work independently at home."*

6 DISCUSSION

This study attempts to broaden adults' participation in computing by deploying contextualized strategies based on andragogy principles for lifelong learning. Part of the goal is to examine how the intervention improves adults' cognitive functions, social collaboration, and other learning experiences.

Notably, reports are showing older adults facing cognitive and emotional barriers when approaching any new technology. These barriers often fall close to a lack of confidence and a fear of failing, which can be amplified by new educational settings [18]. Our study prioritized a user learner-centered approach that emphasizes immediate feedback and manageable challenges that encourage cooperative learning through platforms such as the Scratch application, aligning closely with Amraouy et al.'s [9] recommendation for adaptive learning environments to respond to the learner's motivational state. Besides, older adults also experience frustrations while learning programming. Notwithstanding, this study reveals that their self-confidence and intrinsic motivation can be facilitated through learner-centered interventions.

Following closely with the andragogy principles outlined in Knowles [21] work, our interventions were designed to respect the autonomy and maturity of the adult learners, keeping them in control of their learning process. This approach keeps respect for their self-concept and leverages their past experiences to make the current work relevant and applicable to their lives [8]. This learning style encourages the learner to interact with others to share their experiences and learn together, which is a key compensation for engaging non-traditional learners [15] .

Focusing on the collaboration aspect of our intervention proved to be crucial. By sharing their experiences in the moment, the learners could overcome isolation and barriers that commonly affect adult learners [27]. The community aspect supported individual learning but also fostered much other knowledge sharing from each other, showing similar findings from Antonis et al. [10] about how effective web-based learning designs for adults are. We aimed to use technology to make learning more accessible and relevant to help resonate with the adults' everyday lives. We hope the skills they learned are not only abstract and meaningless but also teach them new ways of thinking. Varying approaches, depending on the type of question, will have immediate applicability to support lifelong learning and boost familiarity with technology in the current rapidly changing digital world [32]. Also, allowing flexibility within the lessons in the workshops and with the varied schedules of the learners was a strategy supported by Hollinworth & Hwang [20] to keep learners engaged in a low-stress environment.

Previous studies show that the benefits of introducing computational thinking and programming to adults are quite high [35]. This study has shown that teaching programming can support older adults by stimulating their brains and keeping them active and up-to-date with digital tech, which is essential for their social and mental well-being [24, 28]. Computing education is typically taught at K-12 and college levels but is recently gaining interest among older adults to start learning programming [12, 26].

Guo [18] revealed that adults are eager to start programming for mental stimulation and challenge but discovered that they often get stopped by cognitive and emotional difficulties. Thus, indicating that certain pedagogical approaches, such as problem-based learning, may not be as effective for older learners, but learner-centered approaches are. Malcolm Knowles's andragogy principles provide a theoretical foundation for adult education. Self-directed learning is one of the key principles that leverage the adult's past experiences,

readiness to learn, orientation to learn, and internal motivation [23]. Applying these principles to computing education can help enhance the learning experiences for adults, making them more relevant and engaging.

Motivation is one of the learning outcomes of computing education for older adults [1]. In tandem with the Nycyk and Redsell [27] study, this study amplifies the need to continue to build on the adult's motivation by focusing on the importance of community-based learning and supportive teaching practices in learning computing skills. Similarly, Ohashi et al. [28] demonstrate the effectiveness of peer instructors and collaborative environments as they are more tailored to older adults' unique needs and ambitions. By combining the lifelong learning and andragogy principles into computing education, we can create a supportive, engaging, and effective learning environment that not only broadens participation but also improves the cognitive function and social well-being of older adults.

6.1 Reflection

For adults, computational thinking is creating an environment with problem-solving opportunities to foster cognitive stimulation. Integrating lifelong learning principles with adult education through platforms such as Scratch and Karel gives accessible and engaging ways to boost cognitive function and teach programming to adults, highlighting the importance of learner-centered approaches. Workshops that include collaboration and real-world problem-solving can help avoid the cognitive decline many older adults have and bring enjoyment through leveraging the adult's past experiences and eagerness to learn. This multifaceted approach and pedagogy can significantly enhance the adult's digital literacy and overall well-being, addressing the challenges and opportunities of adult education.

This study holds the main aspect of the need to adapt computing education to meet the diverse needs of adult learners to maintain success in programs. By integrating andragogy principles, leveraging the community learning environment, and finding appropriate technology, we can increase the educational aspects and enhance their competency in computing. This approach will not only focus on individual learning needs but also contribute to a more digitally inclusive society.

6.2 Study limitation and future work

This study is limited in several ways. For example, the sample size of participants is low and not representative, hence, results cannot be generalized. Although the intervention was conducted in two case studies, yet, the duration was very short. To deepen the understanding of the impact of the study, a longer period is needed. Further, this study recruited educated senior citizens - retirees who could be term "Crème de la crème" of the older community. This could introduce potential bias of social status. Future studies will recruit older adults of lower social status to examine similar phenomena. Meanwhile, barriers such as gathering adults, time limitations, and technology access constituted these limitations. Future studies should keep in mind that a flexible learning schedule could mitigate many of these challenges. Furthermore, this study did not factor in disability-related accessibility issues, which are common in older adults, and the impact they may have on older adults' learning outcomes. For greater inclusivity, future studies will consider accessibility issues as we try to broaden the participation of older adults in computing education.

7 CONCLUSION

Extending computing education to lifelong learners not only broadens their participation but also empowers them to remain active socially, emotionally, and cognitively. This study demonstrates how to explore strategies that conform to adults' learning processes to foster computing education. By contextualizing computational thinking activities and designing adult-focused interventions, this study revealed possibilities of fostering computing education for lifelong learners using andragogy principles. Findings show that adults developed interest in computing and are motivated to continue to learn programming on their own. They self-reported how the intervention stimulates their brain, helping them to improve their cognitive capabilities. These findings provides initial evidence and could be further investigated by future researchers. The study contributes to the literature on broadening participation in computing education by exploring adult-focused learning principles, and our future study will subject its findings to further investigation.

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