Older Adults' Collaborative Learning Dynamics When Exploring Feature-Rich Software

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Collaborative learning has been suggested as a promising approach to help older adults learn new technology, however, its effectiveness has been understudied in the context of feature-rich applications. We conducted an observational study with the aim of identifying aspects of collaborative learning, including characteristics of collaborative partners, that impact older adults' exploratory learning behaviour in feature-rich software. We recruited 22 participants (6 younger adults and 16 older adults) who formed 5 same-age and 6 mixed-age dyads. These dyads worked together remotely to explore a feature-rich application, which was new to them. We classified dyadic interactions into four different collaboration dynamics characterized by distinct attributes. We discovered that effective communication and the ability to navigate the software independently enabled a successful collaboration dynamic that empowered learners. We showed that trust between partners enabled effective communication and we observed that the existing relationship between partners strongly impacted their communication patterns. The more complicated study tasks required participants to validate the correctness of their work and this validation was particularly difficult for some novice older adults who did not benefit from transfer learning and struggled with navigation issues.

CCS Concepts: • **Human-centered computing ~ Human computer interaction (HCI) ~ Empirical studies in HCI**

Additional Key Words and Phrases: Older adults, collaboration, exploratory learning, collaboration dynamics, feature-rich software.

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1 INTRODUCTION

In line with an increase in the diversity of the user population of feature-rich software [43,48], older adults (65+) are using these applications more frequently than ever before [43]. The increase in the statutory retirement age [27,55] and work being a vital part of active aging [7] makes older adults the fastest-growing population segment in workplaces where computers are essential

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elements in daily work tasks [73]. Older adults are also the target users of many new technologies to support independent and healthy living [1,42,61] and to help them build and maintain vibrant relationships [15,57]. Comparing the results of two surveys about older adults' technology use in 2010 and 2019 shows a progression towards more complex software use by older adults [41,73].

Feature-rich software applications typically have interfaces with many options provided through structures such as menus and dialog boxes [48]. Such applications also typically include multiple types of editing/operational modes to enable users to work on sophisticated projects [60]. While there is no explicit definition differentiating feature-rich from non-feature-rich software, prior work has used applications such as MS OneNote, MS Word, GIMP, Revit, SolidWorks, and Adobe Creative Suite as examples of feature-rich software [33,38,43,47]. Due to the complex nature of these applications, learning feature-rich software can be difficult. There is much research on how to improve the learning experience for users [10,13,29,43,48,72], but this prior work has not typically considered older adults as target users. Reflecting on the increase in older adults' use of complex applications, it is important to also consider older adults as target users of feature-rich applications to understand their learning challenges and how we can improve their experience.

While recent research has shown that older adults favor exploration when learning new technologies [54], spending time on exploration gives rise to learning difficulties for older adults [70] that can make the experience frustrating [43,54]. To address such difficulties, prior research has suggested social support to approach learning IT/ICT skills [2,59,70], which older adults themselves also favor [4,64,74]. While collaboration has been suggested as an example of social support during learning, prior research has focused mostly on learning IT/ICT skills and videogames [4,15,35,50,61,74]. As older adults' technology use is no longer limited to basic applications, we focus on older adults learning feature-rich software via exploration and investigate the potential of collaborative learning to support older adults' exploration experience. We conducted an observational study with older adults learning a feature-rich application collaboratively with a remotely located partner. We selected Gather.Town[1] Mapmaker as an example of a feature-rich software application that allows users to design and build virtual spaces for video conferencing, using a wide array of features, menus, and dialog boxes. This creativity support tool was chosen because it would be unlikely to be known by participants (ensuring all our participants were novice learners), and would provide a level of visual engagement and interest to help keep participants motivated. Through our study we aim to investigate the following:

1. What types of collaboration dynamics emerge between older adults and their learning partners?
2. Are there any observable differences between the collaboration dynamics of learning partners of the same versus different ages?
3. What challenges do older adults face when engaging in exploratory learning of feature-rich software?

Our findings reveal that gaining effective support from learning partners is nuanced and dependent on establishing trust between the partners. Furthermore, we found that the initial ability to navigate and explore the software can impact the collaboration dynamic and a lack of such ability can impact trust by a learning partner in a way that hinders communication and creates a negative cycle. In addition, we observed that age per se is not an impactful factor on the

[1] www.gather.town

effectiveness of collaboration. Rather, we found that other characteristics of a partner, such as their expertise and patience towards older adults, are more important. Regarding challenges, we found that some novice older adult users are not as comfortable as younger participants with task progress assessment or error testing in complex tasks.

Our work contributes an initial understanding of how older adults learn and explore feature-rich software when working collaboratively with a partner. Our findings shed light on factors that impact a successful dynamic between learning partners, which directly impacts older adults' exploration success. Further, our results highlight skills that are beneficial for effective exploration of feature-rich software by older adults, such as the ability to validate progress on a task and fix errors.

2 RELATED WORK

2.1 Older Adults Learning Technology and Feature-Rich Application

Computer use by older adults is an active field of study that attracts researchers from different disciplines such as Gerontology, Healthcare, Business, and HCI [73]. Research investigating older adults' technology use has mostly considered IT/ICT and basic internet skills [2,4,42,65,68,70]. In comparison, older adults' use of more complex technologies such as feature-rich software has received much less attention. Previously, older adults mostly used technology for communication, leisure, and information seeking [73], however, a 2019 survey illustrated a progression to more complex software use [41]. Our work is motivated by this shift in that we study older adults learning to use a feature-rich software application.

Among different approaches to learning a new technology, older adults prefer trial and error and exploratory learning [54], but these approaches can lead to challenges during the learning process [43,54]. Common challenges include awareness of functionality, locating and understanding functionality, and especially understanding task flow [29,43]. Reducing the difficulties older adults encounter during exploration can improve their level of satisfaction and effectiveness of the exploration approach, which in turn can lead to increased technology use [70]. Our study contributes further insights on challenges that older adults face as they explore feature-rich applications.

Studies exploring older adults' technology acceptance have demonstrated that the availability of various types of support can reduce the perceived difficulty of exploring new technologies [2,59,70]. Examples of such support include changing system characteristics by providing exploration-supportive facilities [19,43], improving training materials and programs [49,68,74], and providing mechanisms to enable collaboration, community, or social support [31,54]. Among these different approaches to providing support, we investigate *social* support as it is one of the most promising approaches identified [54]. Social support builds on sociocultural constructivism: a theory that frames learning as a collaborative rather than an individual activity, and knowledge creation as a product of social and cultural interactions [63]. We specifically focus on understanding how social support impacts older adults' exploratory learning of a feature-rich application.

2.2 Social Support to Enhance Feature-Rich Software Learning

Researchers have long acknowledged the importance of social support in helping users learn and master complex software. One common approach involves community-based methods, where software users learn from other users. Prior work has investigated several ways to improve community-based social learning, for example, through Q&As that are attached to relevant commands and options in an application's interface [13,45], software tutorials that are augmented with community demonstrations or comments [10,39], and enhanced social media interfaces with special features for sharing software knowledge [22,40]. Prior work has also investigated ways to support community-based 'over the shoulder learning' [72] by helping users identify commands and features that others are using [46]. Collectively, studies of these approaches have demonstrated the value in helping users learn software by leveraging the experiences and perspectives of others. Our work focuses on learning with a single peer, building on the finding that seeking personalized help directly from a peer is one of the most commonly sought-out sources of help for learning feature-rich software [33].

Many studies have investigated one-on-one help for learning complex technology [11,32,33,56,71,72,75]. A widely explored topic in this area is about understanding and supporting remote novice-expert interactions [5,11,12,17,32,33,66]. An important finding from this body of work is that contextual information plays a critical role in effectively resolving issues [11]. For example, automatically attaching relevant supplementary materials (e.g., screenshots of the issue) through a video-call can facilitate a novice's help-seeking process by providing the necessary context to the expert [32]. We leveraged this finding to inform our choice of feature-rich application, which allows context sharing by default. Research has also investigated the trend of seeking one-on-one help from family members, indicating that factors like cost, convenience, comfort, and trust may influence individuals to seek assistance from family rather than professional experts [56]. Motivated by this finding, we study a situation where the older adult is paired with a partner that they know but who is also using the software for the first time.

In the context of collaboratively learning feature-rich software, the focus of prior work has mostly been on younger generations. The findings from this work have been promising. For example, when learning new feature-rich software such as 3D modeling applications, the social context provided by collaborative environments can lead to more successful learning outcomes for children as compared to learning in traditional lecture rooms [23,53]. In another example, learning webpage design software collaboratively resulted in lower cognitive load for the learners than when they learned the software individually [75]. Given that social support and collaborative learning are promising ways for younger generations to learn technology and feature-rich software, we add to this literature by investigating collaborative learning as a means of feature-rich software learning for older adults.

2.3 Social Support to Help Older Adults Learn New Technology

While older adults learning feature-rich software has generally been understudied [52], multiple studies have highlighted the importance of social support and the preference for one-on-one help rather than traditional classes when learning basic IT/ICT skills [49,68,74]. Prior studies revealed that among different forms of one-on-one help-seeking, older adults prefer asking for help from members of their social circle, such as family members, neighbours, and friends [31,54]. Furthermore, of those in their social circle, older adults tend to gravitate towards getting help from their children or grandchildren [20,24]. In fact, older adults are often first introduced to technology by their grandchildren, whose enthusiasm can encourage older adults to continue learning [26,69]. However, seeking technology assistance from younger family members can present challenges, including limited availability of children or grandchildren [30,34], and potential impatience from teenagers, which can hinder older adults' learning process [68,74]. Older adults' fear of being a burden on their younger family members can also deter them from asking questions [4,69]. One potential factor that may contribute to challenges is that younger family members may act as or be viewed as authoritative experts with superior skills, creating an unequal power dynamic that leaves older adults in a dependent position [34]. Getting technology help from a peer of the same age (e.g., a life partner) seems to mitigate some of these problems and is consequently becoming more common [31,44]. These results informed our study design in which we recruited older adults and learning partners (either a younger adult or another older adult) who were *both* newcomers to the feature-rich software used in the study.

Regarding older adults' collaborative learning, which is a different type of social support than asking someone for help, studies have explored learning video games in addition to basic IT/ICT skills. The HiHtaST[2] project [4] organized a peer-to-peer network for mutual support for older adults, where participants from five European countries could learn IT skills together. The opportunity for collaborative learning provided a way for older adults to share tips and exchange knowledge, which in turn reduced their fear of learning a new technology and increased their self-efficacy. When playing videogames with a partner, results have shown that the negotiation and discussion sparked by collaboration increased older adults' understanding of the game and reduced mistakes, which made the experience less frustrating than when playing individually [50]. While there are positive impacts when playing games with both younger and same-age partners, the dynamics can differ in important ways [61]. For example, when older adults play videogames with a partner of their age, they can understand each other's language easily [61], which helps with gameplay [50]. Also, observing a same-age partner performing a task can increase an older adult's confidence, making them more comfortable exploring the software and applying the actions that they already have learned [35,42,50]. On the other hand, playing videogames with younger generations has the benefit of breaking the stereotypes that both generations hold towards each other [15]. As part of our study, we investigate how differences in interactions between same- and mixed-age pairs might manifest in the context of learning feature-rich software.

While collaborative learning has been a promising approach for younger generations to learn a new feature-rich application and for older adults to explore IT/ICT technologies or videogames, its impact on older adults' exploration of feature-rich applications is unknown. The nature of exploratory learning of feature-rich applications is different from learning basic IT/ICT skills due to their complexity. With videogames, which are arguably the closest in terms of application complexity, younger and older adult learning partners often bring vastly different domain expertise to the collaborative learning experience [15], but this may not be the case with other feature-rich applications. Also, it is unclear what characterizes an ideal partner for older adults learning feature-rich software. Our work aims to contribute to this research area by investigating the effects of partner interactions on older adults' exploration of feature-rich software when the partners are of a similar age and when the older adult is collaborating with a younger partner.

3 METHODOLOGY

We conducted an observational study to investigate how older adults experience exploring a feature-rich application for the first time while collaborating with a learning partner from their social circle. Our goal was to understand what type of interaction patterns would emerge between partners in different age dyads and how those interactions would impact older adults' exploratory learning behaviours.

[2] Hand in Hand to a Social Tomorrow

3.1 Feature-Rich Application

In selecting a feature-rich application to use in our study, we aimed for an application that is easy for novices to start exploring while still providing a wide range of options and editing modes for advanced projects. These criteria align with principles of a well-designed "creativity support tool" (CST) [60]; CSTs are often feature-rich, which increases their complexity, and makes them daunting for novice users to explore [25]. Resnick et al. characterize 'good' CSTs as having 'low walls' and 'high ceilings', which make it easy for novices to get started while still providing enough complexity to allow deep skill development and unlimited creative possibilities [60]. These tools usually support trial and error [60], which can remove some of the fear associated with exploration [42,50]. Given these characteristics, we decided to find a CST that would be an appropriate choice of feature-rich software for our participants to collaboratively explore and learn.

With these criteria in mind, we chose the Gather.Town Mapmaker as the feature-rich software for our study. Gather.Town itself is a web-based spatial video-conferencing platform where every user is represented as an avatar, and users meet in virtual 2D spaces where they can move around and explore the world together and interact with objects, while seeing and hearing one another via proximity chat (Fig. 1).

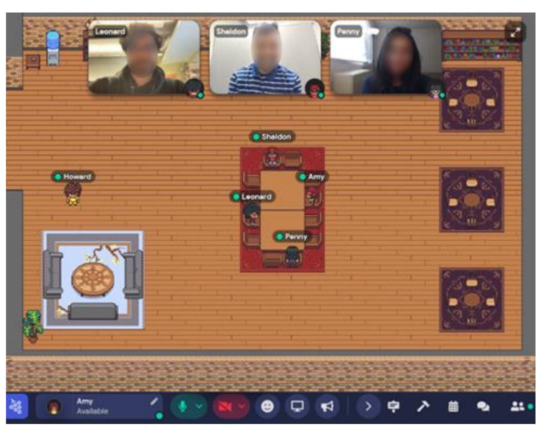

Fig. 1. Users having a conversation in the Gather.Town platform. The blurred images do not belong to any of the study participants.

The spaces that users inhabit in Gather.Town are designed using the Gather.Town Mapmaker (GTM). GTM is a web-based application that allows users to design 2D virtual spaces for Gather.Town (GT) either from scratch or by starting with provided room templates. GTM is similar to systems that designers use to lay out the different worlds/levels in an adventure-style videogame. In our study, each participant created a virtual cottage.

In addition to satisfying the feature-rich and CST software criteria, another advantage of using GTM is that as participants designed their spaces, they could go into GT to both look at their spaces and talk to each other through GT's video-conferencing. Fig. 2 depicts how users could switch back and forth between GT and GTM.

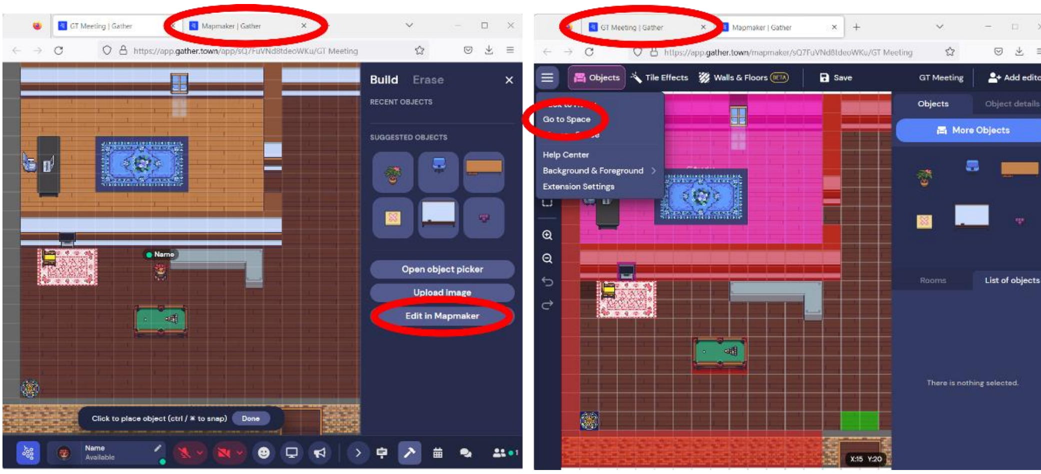

Fig. 2. Left screenshot: user is currently in a virtual room and can switch to GTM by clicking on "Edit in Mapmaker" in the right panel or clicking on the other tab if GTM is already open. Right screenshot: user is in GTM and can switch to the space by clicking on the "Go to Space" option in the top-left menu, or by clicking on the tab for GT.

3.2 Apparatus

We chose not to have participants co-located during the study to reduce the likelihood of one partner becoming dominant and doing all the work. Therefore, to maximize each participant's involvement in performing the tasks, each participant worked on a separate computer in a separate location. There was no need to install any software as GT and GTM are web-based applications that can be accessed using a browser. The fact that our participants were in a shared GT space eliminated the need to use an additional communication tool; the dyad could communicate with each other and the researcher through GT. In addition, we asked participants to share their screens in GT throughout the study to allow their partner and the researcher to see their actions in GTM. We gave participants the option to either participate in the study remotely or to come to our campus. Participants who came to campus were placed in separate study rooms.

3.3 Procedure and Tasks

The study took place over two sessions: a *Contextual Orientation* session, where we introduced participants to the GT environment; and a *Design Tasks* session, where participants designed a virtual room in GTM. We elaborate on each of these sessions below.

3.3.1 Contextual Orientation Session. At the beginning of the *Contextual Orientation* session, the researcher asked participants to fill out a background questionnaire (Supplemental Materials-Appendix A). Next, participants watched a 3-minute introduction video that explains fundamental GT concepts. Then to allow the participants to experience each feature, the researcher showed participants a virtual cottage as a sample of what they would be asked to design in the second session. Participants had time to roam around in the sample cottage and find examples of the concepts introduced in the video. Finally, participants completed a short task using the "interactive build mode" in GT, a feature which allows users to engage in decorating a virtual space by placing or erasing virtual objects (Supplemental Materials-Appendix B). This feature provides a very simplified subset of what users can do in the GTM and was meant to serve as scaffolding for the second session.

3.3.2 Design Tasks Session. We scheduled the second session, *Design Tasks*, in the same week as each dyad's *Contextual Orientation* session. During this session, the researcher first shared a 2-minute video about GTM to demonstrate how participants should open it in another tab and its main editing modes. Then, participants had one hour to perform tasks (described below) while collaborating. During the tasks, the researcher asked participants to talk to each other. The researcher prompted participants to talk after a silence of more than ~2 minutes. To avoid participants becoming overly frustrated, the researcher also gave tips when participants were unable to progress even with the help of their partner. This happened when both partners turned to the researcher after discussing how to perform a task and expressed that they had given up and needed a tip from the researcher. Only then would the researcher provide limited guidance, such as identifying which aspect of the space was related to the task. After going through the tasks, participants filled out a post-study questionnaire (Supplemental Materials-Appendix C). The second session concluded with a separate semi-structured interview (Supplemental Materials-Appendix D) with each participant (~15 minutes each).

Task-oriented exploration is more common in software learning than task-free exploration because users usually focus on performing a specific task when exploring software for the first time [62]. So, we assigned each participant a separate empty room in GT that they could decorate progressively by following prescribed tasks which increase in challenge level.

GTM has different navigation menus and editing panels that allow users to work on different aspects of their space: "walls and floors", "objects", and "tile effects". Table 1 shows a summary of our three task sets along with the steps that we required participants to take (full task instructions can be found in Supplemental Materials-Appendix E).

Table 1. Task description; three sets of tasks with 7 steps in total.

Task set (Duration)	Task steps
1 - Walls and Floors (15 minutes)	1. Erase 20 boxes in the cottages. 2. Place 30 wall tiles (three rows) in the cottages. 3. Change the floor patterns of the cottages.
2 - Objects (20 minutes)	4. Place 5 objects in the space, replicating one of four provided room designs. *Note: All the room designs required users to use advanced features of "objects" mode such as rotating objects, changing colours, and layering placement.*
3 - Tile Effects (25 minutes)	5. Make walls, tables, etc. "impassable". 6. Create a "private area". 7. Create a "portal" to each other's cottage. *Note: This task set was more abstract and required setting "non-visible" properties of the map and switching between rooms.*

3.4 Participants

We advertised the study on social media, on our university campus, in the local community, and in the newsletters of some universities' retiree associations. We compensated each participant with $45 CAD. To prevent the awkwardness of interaction with a stranger, we only accepted dyads of participants who knew each other (e.g., family members, friends, or colleagues). We were able to recruit 16 older adults and 6 younger participants which formed 6 mixed-age and 5 same-age dyads. All the older adults had post-secondary education and 6 of the 16 had PhD degrees. As for the younger participants, 4 of the 6 had finished post-secondary education, while the remaining two had completed middle school or high school.

User characteristics, such as their prior software expertise, play an essential role in the exploration process [9]. The focus of our study was on how novice older adults explore feature-rich software; therefore, we recruited dyads of participants who had zero prior experience using GTM, with at least one older adult (65+) in each dyad. We excluded participants who did not know how to use computers and the Internet for basic activities such as emailing. To gather further information about the participants' background, the pre-study questionnaire asked about the participants' level of technology comfort [6] as well as their prior experience using various types of technology. In terms of technology comfort, participants answered questions on how comfortable they were performing various tasks with computers [6]. Most older adult participants answered with "Somewhat easily" or "Very easily" for "Keyboard and Mouse", "Email", "Finding Information Online", and "Entertainment" tasks, but reported less comfort with "Managing Appointments" and "Printer" tasks (Supplemental Materials-Appendix F). We also asked how frequently the participants use four types of computer applications. Fig. 3 shows that almost all the older adult participants had zero experience using sandbox games and just a few were occasional or frequent users of graphics software.

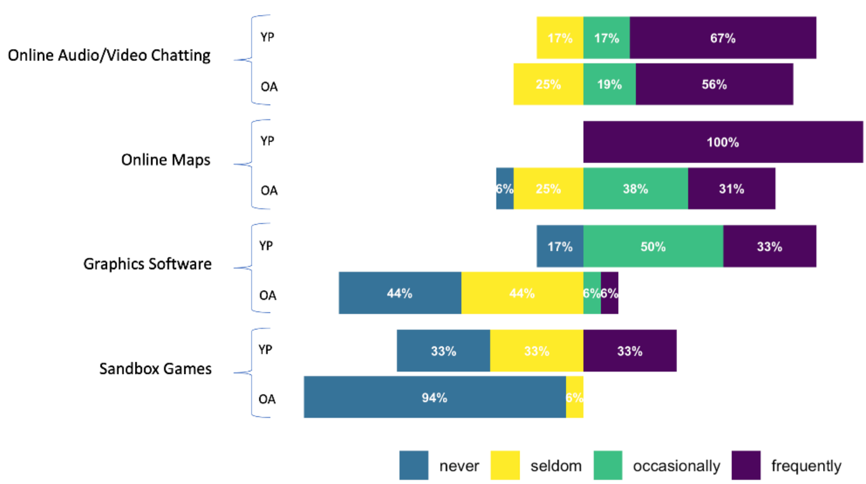

Fig. 3. Participants' frequency using different types of technology, separated by older adults (OA) and younger participants (YP). Example: 56% of older adult participants use video/audio chat frequently.

3.5 Data Collection

Our main source of data was the participants' interaction with each other and the software in the *Design Tasks* session. As the participants were working on the tasks, we recorded their screens (participants shared their screens the whole time) to capture their interaction with GTM along with their voice and video feed to capture the interaction between learning partners.

After the *Design Tasks* session, we collected Likert-scale data through the post-study questionnaire, which was modified from Rice et al. [61], to capture participants' perceptions about their performance and how they communicated with their partner. We also conducted separate semi-structured interviews with each learning partner to follow up on questionnaire answers and to elicit further perceptions of their collaborative learning experience with GTM.

3.6 Data Analysis

We started by analyzing the learning partner's conversations in the *Design Tasks* session. Our objective was to develop a set of codes that could effectively describe the collaborative dynamics that emerged between the learning partners while working on the tasks. We employed an open coding approach [16], and customized it to align with the conversational nature of collaborative activities. First, the researcher who conducted the study transcribed the conversation between learning partners and then coded each interaction instance. Then three researchers revised and refined the initial codes collaboratively through three iterations by discussing different samples for each code. The final codes are described in Section 4.1.

We continued our analysis by examining the shared screens of each participant during their interactions with the GTM and their final room design. The primary objective was to gain an understanding of the participants' level of task success. The researcher who conducted the study counted the number of task steps (out of 7) that were correctly completed, either partially or fully, by each participant. The purpose of reviewing the recordings was to gather evidence of task success that may not be apparent solely by examining the final room design, such as identifying whether participants placed two objects on top of each other. Additionally, a secondary objective of reviewing the video recording was to gain insight into the challenges encountered by participants while completing the tasks. The researcher carefully documented instances that contributed to lower task success for each participant.

Additionally, we employed thematic analysis [8] on both the researcher's notes on the challenges and the participants' interview responses. The analysis of the researcher's notes aimed to uncover the reasons behind the participants' challenges, while the analysis of the interviews aimed to reveal the underlying reasons behind the participants' opinions about their partners and their overall experience. We utilized an inductive approach to thematic analysis, without a pre-existing coding frame, allowing the codes to emerge organically during the analysis process. The initial step involved the researcher who conducted the study familiarizing themselves with the data. Next, they generated initial codes and embarked on the search for recurring themes using the same approach applied to analyze participant interactions.

While the focus of our analysis and findings is on the qualitative data, we also report some preliminary findings from the post-study questionnaire, where we compared older adults' and younger participants' responses using two-tailed t-tests. We report on these quantitative results to provide further context for the qualitative findings. In our reporting, we consider results with $p\text{-value} < 0.05$ as significant and $0.1 > p\text{-value} > 0.05$ as an indication of a trend. We used the Shapiro-Wilk test to check for normality (all p-values were > 0.05).

4 FINDINGS

We begin by presenting collaboration dynamics that emerged between the learning partners, highlighting distinctive characteristics that we observed in each dynamic. Then, we discuss the potential relationship between elements of these dynamics and task success. Finally, we describe key factors that seemed to contribute to the successful exploration of the software. Throughout the rest of this paper, we use S and M to indicate same-age and mixed-age dyads respectively, and O and Y refer to older adults and younger participants. For example, S1-O_2 refers to older adult partner #2 in same-age dyad #1.

4.1 Collaboration Dynamics

Our open coding process for dyadic interactions (see Section 3.6) resulted in 17 unique codes (see Supplemental Materials-Appendix G). Of these codes, we found the 7 codes listed in Table 1Table 2 to be most useful in differentiating collaboration dynamics based on their definition. These 7 codes also had the highest standard deviations in frequency across dyads (Appendix G), indicating their utility in differentiation. After counting the occurrences of each code for each dyad, including who was involved in each interaction, we realized that in the S1 and S2 dyads, the interactions were mostly between the researcher and the participants as opposed to being between the partners. The average number of interactions between partners in these two dyads was less than half of the average interactions for all other dyads (93 vs. 194), and the average number of times they interacted with the researcher was more than three times that of other dyads (171 vs. 52). Due to the significant amount of aid provided by the researcher to enable the four participants in these two dyads to progress with the tasks, we excluded them from further analysis.

Table 2. Examples of codes developed through the open coding method

Code	Description of Code	Example Interaction Excerpts
Discussion	Both partners bring their own thoughts and ideas to do a task.	"Is portal an object?" (M6-O) "Maybe they are tile effect." (M6-Y) "if you go to objects and type portals you get portals" (M6-O)
Question	Question that was related to how to do a task or concepts of the GTM.	"Can you tell me where private area is?" (S1-O1)
Correct Answers	Answers to a question that were correct, even if they were not understood by the asker.	"You first go on the wall, right?" (M7-O) "Yes, first click on stamp then click on the wall and then where you want it on the yellow" (M7-Y)
Correct Tips	Unsolicited (but correct) advice about how to do a task.	"You can go all the way over to the right. Yeah, and below impassable there [are] spawn portal and then private area. And then you need to select or type a new name" (M9-Y)
Incorrect Tips	Unsolicited (incorrect) advice about how to do a task.	"So now just go to the laptop area. Move your mouse to that. Try to click, so it's only making the laptop thing private" (M11-Y)
Busy Answers	Answers that indicated one's reluctance to respond to their partners' questions.	"How do you change the object? Do you remember that?" (S3-O1) "No, no. I'm having trouble, I had a rug and I erased it and now I cannot get it again." (S3-O2)
Current stage	A partner informing the other about what they are doing.	"This time I drag it over here. And leave it there. Ok. Wait, I got two rugs here now." (S4-O1)

For the remaining dyads, we graphed the frequency of each code, excluding those involving interactions with the researcher. These graphs suggested four different partner dynamics: *dominant-follower*, *equal collaboration*, *on demand*, and *individual exploration*. We classified each dyad according to the most repetitive and prevailing dynamic type between partners, as dyads often exhibited patterns of different dynamics. Table 3 lists our classifications, and we elaborate on the nature of the dynamics below.

Table 3. Clustering dyads based on the dominant dynamic between partners.

Dynamic Types	Dyads
dominant-follower	M8, M9, M11
equal collaboration	M6, S4
on demand	M7, M10
individual exploration	S3, S5

4.1.1 Dominant-Follower - Collaboration Dynamic. The most distinct attributes of this dynamic are unidirectional help giving and lack of discussion. As the example in Fig. 4 shows, the dominant partner gave constant tips to the follower partner and almost all the questions came from the follower partner.

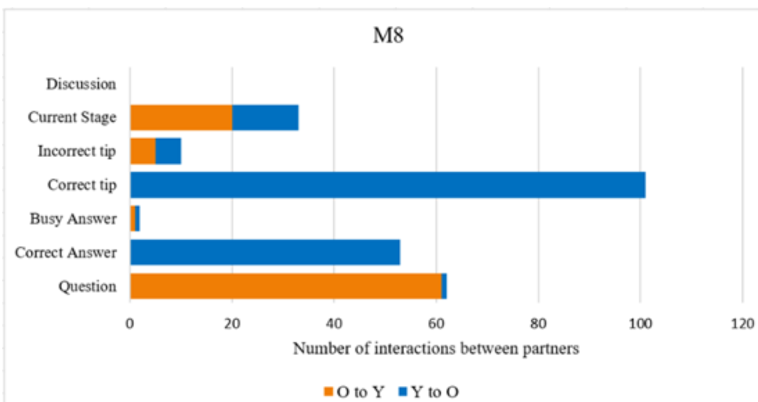

Fig. 4. Frequency of occurrence of each code of interaction in M8 (example of *dominant-follower* collaboration dynamic).

This dynamic characterized mixed-age dyads where the older adult acted as the follower and their younger partner played a dominant role. In cases where partners were family members (M8 and M11) the dominant partner would often ask the follower to wait for them to complete the tasks first and then give step-by-step instructions to them, as the following quote illustrates:

> M8-Y to M8-O: “So you’re done here. Now I’m gonna do my task. You need to have patience and wait for a while.”

Another important communication element was the dominant partner’s reaction to their older adult partner’s (possible) mistakes. As the quote below illustrates, some younger partners reacted negatively when their older partner would make a mistake, especially in family relationships:

> M8-Y to M8-O: “no no no no, [don’t click] on that one”, “hold on let me figure out. wait, don’t do anything”.

In rare cases where the older adult partner wanted to express their opinions, their younger partner seemed reluctant to engage in discussion. In the example that follows, the older adult partner in M11 wanted to correctly draw the younger partner’s attention to the fact that they need to name the private area (i.e., give it an ID), but the younger partner was reluctant to listen:

M11-Y: "Just go to the laptop area. Move your mouse to that and try to click. [...] We're done, click save."
M11-O: "[...] you can give the name laptop area." [This is a correct assertion/suggestion]
M11-Y: "It's not about naming anything." [This is incorrect – a name/ID is required for private areas]
M11-O: "Ok, then save?"
M11-Y: "Save it, it should be fine."

These types of negative reactions appeared to discourage older adults from expressing their opinions and increase their dependence on their dominant partner. In addition to making communication challenging, judgmental partners seemed to make the older adults hesitant to explore the software. The older adults in this dynamic were trying to explore the software at the beginning of the *Design Tasks* session but gradually seeing their younger partner's impatient reactions led them to just sit and wait for their partner to tell them what to do and to seek approval before doing anything.

4.1.2 Equal Collaboration - Collaboration Dynamic. In the *equal collaboration* dynamic, we observed both partners discussing their thoughts and opinions regarding how to do each task by providing tips and answers instead of one telling the other what to do (Fig. 5).

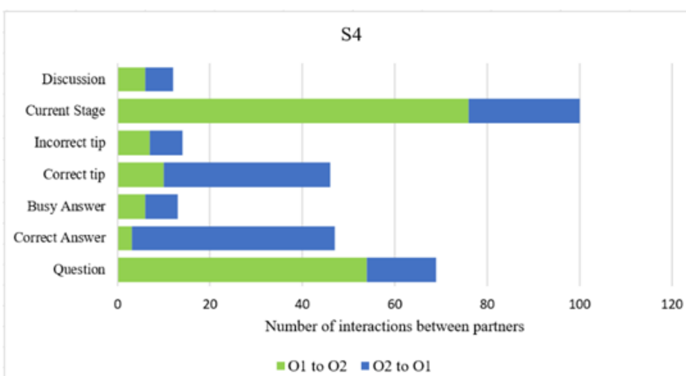

Fig. 5. Frequency of occurrence of each code of interaction in S4 (example of equal collaboration dynamic).

Here is an example of a discussion that occurred between partners in S4 around how to make a portal (task step #7):

S4-O_1: "Pick portal type, portal to a room, portal to another space. That's what I should have?"
S4-O_2: "[...] I put one to my cottage and one to your and I pressed confirms and nothing happened."
S4-O_1: "input space to portal to [S4-O_2]'s cottage."
S4-O_2: "well, I did that, and I press confirm and nothing happened."
S4-O_1: "you should put my name"
S4-O_2: "[...] maybe it doesn't like being called that." [they continued discussing]

4.1.3 On Demand - Collaboration Dynamic. We mostly observed this dynamic in mixed-age dyads. Unlike the *dominant-follower* dynamic in which the older adults were mostly passive in terms of exploring the software, in the *on-demand* dynamic, older adults explored the software actively and asked questions only when they could not find the answer themselves first. As Fig. 6 shows, in contrast to the *equal collaboration* dynamic, there was less discussion surrounding issues, with the younger partner typically providing the answer quite directly by switching to the older adults' screen to get additional context and then telling their partner what to do.

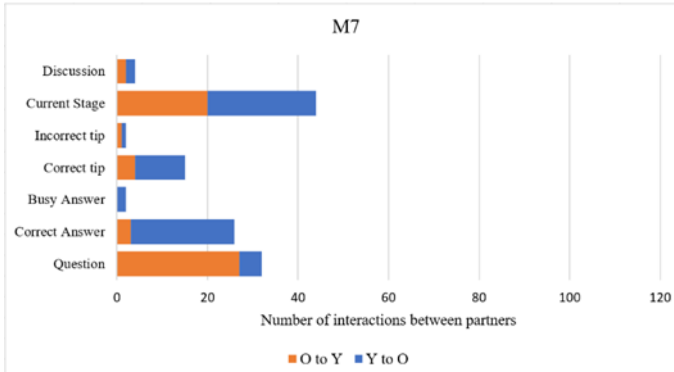

Fig. 6. Frequency of occurrence of each code of interaction in M7 (example of on demand collaboration dynamic).

Younger partners were typically ahead of the older adults in task completion. We observed differences in how the younger partner reacted to this. In M7 (where the partners were friends), we observed that the younger participant tried to stay in sync with the older adult such as by continuing to decorate their cottage while waiting for their partner to move to the next task. In contrast, in M10 (where the partners were family), the younger participant tended to express the fact that they were ahead, as illustrated by the following excerpt:

M10-O: "OK, now we need a computer."
M10-Y: "OMG, [they are] still at the computer. [laugh]"
M10-O: "oh, you have the computer already?"
M10-Y: "I finished my room."
M10-O: "[...] well, hang up a picture or something."

4.1.4 Individual Exploration - Collaboration Dynamic. In the *individual exploration* dynamic, which characterized two same-age dyads, participants seemed more focused on individual task success rather than collaboration, which led to "busy answers" to questions (Fig. 7).

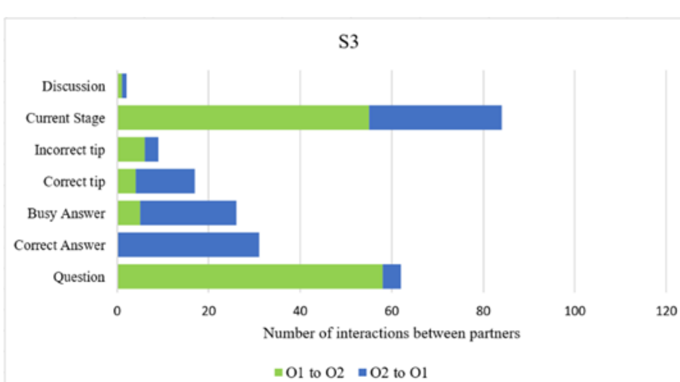

Fig. 7. Frequency of occurrence of each code of interaction in S3 (example of individual exploration collaboration dynamic).

As an example, S5-O_2 was having difficulty placing the walls while their partner (S5-O_1) had already completed this step and was currently experiencing a new problem with the eraser mode.

When S5-O_2 asked a question about placing walls, S5-O_1 responded with their own problem, essentially ignoring their partner's question:

> S5-O_2: "[...] Did you go to small too?"
> S5-O_1: "I don't seem to have anything here. I got my bottom, my one wall and I had the other wall. And then I lost it [...]"
> S5-O_2: "Uh-huh how did you rotate your walls? The arrows?"
> S5-O_1: "I can't remember where to find those [they are looking for a way to put walls again for themself]"

Note that in a similar situation in the *on demand* dynamic, the younger partner would quickly switch to the older adult's screen to help them. By contrast, in *individual exploration*, the partners seemed too busy with their own problems to help each other.

In addition to busy answers hindering the communication between partners, we also observed some older adults having difficulty trusting that their partner could help them, particularly at the start of sessions. For example, further into the above interaction instance, S5-O_1 experienced a new difficulty placing the walls but did not discuss the issue with their partner, relying on self-exploration, which was not leading to a solution. After the researcher prompted them to talk to each other, S5-O_1 asked their partner about the walls, was able to apply their partner's tip, and seemed surprised to find it helpful. After that, we observed more questions and discussion between the two participants in this pair as S5-O_1 realized their partner's helpfulness. Although these instances encouraged more discussion, it remained comparatively lower than what we observed in dynamics characterized by extensive communication and discussion such as *equal collaboration*.

4.2 Task Performance

To examine potential relationships between each dyad's collaboration dynamic and their overall success in performing the study tasks, we assessed task success following the process described in Section 3.6. Fig. 8 depicts task success (horizontal axis) plotted according to each dyad's dominant dynamic (vertical axis). Each shape represents one participant and partners in a dyad have the same colour. Participants who continued to decorate their cottages while their partners were being interviewed are highlighted with a star.

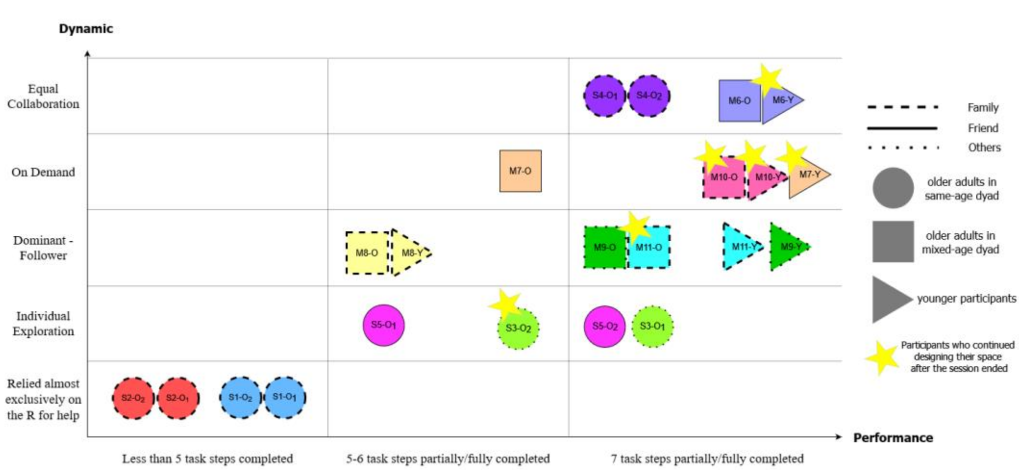

Fig. 8. Participants' task success (x-axis) plotted based on the collaboration dynamic (y-axis).

All the participants in the *equal collaboration* and *on demand* dynamics achieved moderate or high levels of success in doing the tasks as they were able to complete more than 6 of the 7 tasks fully or partially. Note that the only mistake that M7-O (*on demand*) made was when their younger partner was in their own cottage and unavailable to answer their question, otherwise they likely also would have achieved a high level of success. On the other hand, some of the older adults in the *dominant-follower* and *individual exploration* dynamics were less successful. A notable property of the *equal collaboration* dynamic is that partners tended to achieve a similar level of task success, whereas we tended to observe larger gaps between partners in other dynamics.

As we discussed in an example in Section 4.1.1, the dominant partner could have completed the private area task more quickly and easily if they had engaged with the older adult's (correct) opinion about how to complete the task. This lack of discussion stands in contrast to the interaction instances for an *equal collaboration* pair discussed in Section 4.1.2 around creating a portal. In the latter instances, open communication enabled participants to share their opinions and insights on how to perform the tasks while in the former, younger participants did not allow the conversation to form. Similarly, it became evident that participants in *individual exploration* dynamics could have collectively achieved a higher level of task success if they were more open to discussion. For instance, we saw examples of participants giving each other busy answers or not trusting each other to ask questions in Section 4.1.4 even though they had the answer to each other's problem. This explains the gap in task success between partners in *individual exploration* dynamic demonstrated in Fig. 8. In contrast, in *equal collaboration* and *on demand* dynamics, partners would immediately share newly acquired knowledge through either discussion or help-seeking, resulting in higher task success collectively. In summary, it appears that a lack of discussion and communication hindered participants from sharing knowledge and helping each other, thereby limiting their ability to achieve a higher level of task success.

Another notable characteristic that distinguishes more successful dynamics from less successful dynamics was the older adults' ability to independently initiate software exploration. By comparing the interaction instances in *on demand* dynamics versus *dominant-follower*, we noted that older adults engaging in exploring the feature-rich software gained a deeper understanding of the tasks. Older adults in *on demand* dynamics would start exploring the software themselves, which would lead to questions about how to perform a task; they would complete the tasks as they gained a deeper understanding through their curiosity. However, older adults in a *dominant-follower* dynamic would only partially complete the tasks by "blindly" following instructions; their lack of an initial ability to explore the software prevented them from engaging with the tasks. The impassable tiles task provides an example. In the *on-demand* dynamic, older adults would actively engage with the software and the task. Through this exploration they seemed to gain an initial understanding of an impassable tile and how and why to make one. This initial understanding helped them to apply tips and answers from their partner. On the other hand, older adults in the *dominant-follower* dynamic would simply follow their partners' instructions to make only one row of wall impassable. Then, due to their limited understanding of the task's purpose and procedure, they would not make the second row impassable, possibly because they didn't understand what they were doing or why.

With only 2-3 dyads per dynamic, we acknowledge that these observations are based on sparse data and this link between collaboration dynamic and task success needs to be verified with larger sample sizes in future studies.

4.3 Participants' Perceptions of Collaborative Learning

We analyzed data from the post-study questionnaires to get a sense of how participants viewed their collaboration experience. We clustered questions into three different constructs: communication, co-operation, and competence (Appendix C). We then used two-tailed t-tests to examine differences between participants' perception in each construct based on their age and dyad type (same-age vs. mixed-age). Here we describe the significant differences and trends. We use data from the interviews and interaction coding to provide further context for these results.

Older adults assessed the communication with their partners more positively (mean=4.75, SD=0.32) than younger participants (mean=4, SD=0.71) in mixed-age dyads, a difference that was significant (t_7 = -2.37; p=0.049). We also observed a trend (t_6 = -2.11; p=0.079) suggesting that older adults had a more positive perception of the co-operation (mean=4.47, SD=0.33) than the younger participants (mean=3.57, SD=0.99). These differences may be related to the fact that almost all the younger participants claimed to be ahead of their partner and felt that they provided more help than they received. An example quote from the younger partner in M8 illustrates this perception:

> M8-Y: "[...] I wasn't really benefited from my [partner], but I was helping [them]. So, it was OK for [them] but not OK for me. [...]"

This sentiment aligns with both the older adults' perceptions of the interactions and the results of our open coding. Most of the older adults in mixed-age dyads expressed that they asked more questions of their partner compared to the other way around and they found their younger partners very helpful. Our coding revealed that older adults in mixed-age dyads asked 50 questions on average of their younger partners while younger participants asked 1 question on average of their older partner. A similar trend is observed for correct answers and tips in mixed-age dyads, as younger participants gave 74 tips or correct answers, compared to 7 for older adults.

Older adults in mixed-age dyads assessed the communication with their partners more positively (mean=4.75, SD=0.32) compared to those in same-age dyads (mean=4.2, SD=0.51), a difference that was significant (t_{14} = 2.66; p=0.019). One reason might be that 12 out of the 16 older adult participants expressed that they preferred working with someone who knows more than they do. Having a partner with a similar level of knowledge about the software (in same-age dyads) was distracting and frustrating for some as they had to listen to their partner talking about their own issues rather than providing help.

> S3-O_2: "I would say [collaboration with my partner] was frustrating for me at times, because I was also having the same challenges, but I felt like I had to answer what [they were] looking for, before I can go on with my own."

However, some of the older adults were worried about being a burden on the more knowledgeable partner:

> M7-O: "I guess the only [concern with collaborative learning is], because with [M7-Y], knowing a lot more than I do, I feel a little bit like I maybe make it more frustrating for her because I'm always needing more help."

In summary, our findings illustrate an interesting tension: older adults struggled when working with a same-age partner with a similar skill level and stated a preference for working with younger partners whom they believed are more skillful and knowledgeable. However, older adults also worried about being a burden to younger partners and we observed that having a knowledgeable partner did not always lead to successful interaction or exploration.

4.4 Complex Task Assessment Hindering Software Exploration

One way that feature-rich software applications differ from simpler software is that they often enable users to engage in complex, open-ended tasks. While this is often a positive, it introduces complexity in that users must be able to navigate all the steps necessary and be able to determine if the set of steps they have taken have resulted in the desired outcome. In coding the *Design Tasks* session interactions, we observed that many participants did not easily engage in assessing whether they had correctly completed some of the more abstract or complex tasks in the study. Even though the instructions for each task set indicated that participants should visit their own cottage in GT to make sure their changes had their intended effects, only one of the older adults did so without prompting. Table 4 shows that all the younger participants tried to check their work and fix mistakes, while only 5/16 older adults did so. Older adults did not appear to intuitively switch to GT to check whether their GTM actions had the desired results. Our thematic analysis revealed two major obstacles to task assessment for older adults: navigation issues and difficulties knowing how to determine if they had done the task correctly.

Table 4. Number of participants who visited their cottages and subsequent error testing by age and dyad type.

Participants age and dyad type	Older adults (Same-age dyads)	Older adult (Mixed-age dyads)	Younger participants
# Participants who did not visit their cottages at all	2/10	0/6	0/6
# Participants who visited the cottages for the first time without prompting	0/10	1/6	3/6
# Participants who visited the cottages for the first time after being prompted	8/10	5/6	3/6
# Participants who attempted to test and then fix mistakes after visiting cottages	2/10	3/6	6/6

Our study involved three different levels of navigation and effective testing required comfort with all three. As the first step, participants needed to visit their cottages to assess their progress, which required them to navigate from GTM to the GT tab (see Fig. 2). After that, they needed to navigate in the GT environment to get to their cottages by first closing the task instruction poster (which occluded the Gather map when being viewed) and then moving their avatar to their cottages. Finally, after visiting their cottages and finding mistakes, they needed to switch back to the GTM tab and navigate between different modes and dialog boxes to correct their mistakes. Five out of 16 older adult participants were uncomfortable using their arrow keys to move their avatar in GT. Other older adults struggled with other navigation levels, such as switching between tabs and/or views. What is particularly relevant is that these navigation issues also made communication with their partner difficult for older adults as navigation was also needed to switch to the GT tab and then change the view to their partner's shared screen to see the partner's interaction with the software. This meant that it was difficult for older adults to check their progress against their partners' progress, or to get help from their partner in assessing correct task completion.

In terms of assessment, 7 out of 16 older participants did not know how to test if they had done a task correctly, even though they were able to navigate to their cottages. For example, they would ask the researcher how to check if the portal was working. On the other hand, only one of the younger participants (in only one task step) could not assess their progress and asked the researcher for help. Most of our older adult participants had very little experience with sandbox games and graphics software (see Fig. 3), applications that could enable transfer learning [36,58] about virtual world interactions and complex object editing. These participants did not know how to assess whether they had correctly added effects such as impassable walls, private areas, and portals between rooms. For most older adults, their first solution to this assessment uncertainty was to ask the researcher instead of checking their cottages themselves. This lack of transfer learning was described in a few interview responses:

> M10-Y: "[M10-O] is very just not used to this sort of stuff [and this made it challenging]. This is in a way similar to games. My friends and I would play like Animal Crossing [...] this is sort of similar in the way that you're placing things and creating spaces and [M10-O] just doesn't have that sort of experience [...]"

> M9-O: "[...] I have never played computer games at all, so I was pretty unaware of couple of things. So, I depended on [M9-Y] a lot."

5 DISCUSSION

Our study investigated how older adults explore a feature-rich software application for the first time while working with a learning partner. Our first research question asked what types of collaboration dynamics emerge between older adults and their learning partner. Our findings illustrate the nature of dyadic interactions through four types of collaboration dynamics that emerged from our detailed coding: *dominant-follower*, *equal collaboration*, *on demand*, and *individual exploration*. Our findings also shed light on dynamic characteristics that appeared to contribute to task success, including open communication and comfort with independent exploration. Our second research question asked about possible differences between the collaboration dynamics of same-age and mixed-age pairs. Our description of these dynamics, along with participants' opinions, provides a lens through which to examine potential influential factors other than partner age that may have impacted the collaborative learning and the level of task completion of each dyad. In other words, our results indicated that age was potentially less influential than other dimensions of the partnership, such as each partner's previous experience with similar software and the nature of the relationship between the partners. Our third research question asked what challenges older adults face when engaging in exploratory learning of feature-rich software. Our findings indicate that some older adult participants had difficulties assessing complex task progress or checking for errors at least in part owing to struggles with navigation and lack of familiarity with similar software. Below, we elaborate on our findings and discuss implications for design. We also discuss limitations of our study and directions for future work.

5.1 Mutual Trust Between Learning Partners Facilitates Collaboration and Exploration

While the importance of discussion during collaboration has been highlighted in the literature (e.g., during collaborative gameplay [50]), our study sheds further light on nuanced dynamics that can empower/inhibit open discussion when older adults are working with a software peer. For example, our findings suggest that younger participants' reluctance to listen to their older adult partners might have decreased older adults' willingness to participate actively in discussions. At first glance, one might suspect that this type of behaviour originated from the common stereotype that younger generations hold towards older adults, i.e., that older adults are not capable of learning new technology [61]. We did not, however, uniformly observe this stereotype manifest itself across our mixed-age partners. While 3/6 mixed-age pairs assumed a *dominant-follower* dynamic, 3/6 exhibited dynamics with much more discussion *(equal collaboration* and *on-demand).* In looking at the different relationships between the partners, we observed more use of patronizing language and impatience towards older adults in pairs who were family members (mostly parent-child) compared to dyads who identified as friends. This may be due to younger family members having pre-existing assumptions about their older relative's inability to learn new technologies and/or patterns of taking over and fixing technology for their older relatives instead of taking the time to teach them how to use the technology and deal with issues that arise. This observation aligns with prior research showing that some older adults report disempowering and ageist practices when receiving technology support from younger family members [14,34,68,74].

One solution for building trust between older adults and younger learning partners might involve considering methods to educate family members on the importance of being patient and avoiding stereotypes. For example, a 2017 study suggested teaching teenagers in school about how to tutor older adults [68]. One of the benefits of co-playing video games is enhancing intergenerational relationships and breaking down stereotypes [15,61]. Programs that provide an opportunity for different generations to learn feature-rich software together could have similar effects. Also, since we observed slightly more positive interactions in the mixed-age dyads who were not family members, it might be worth considering using people in an older adults' *outer* social circle to provide collaborative learning support, rather than *close* family members. While research has shown that partner familiarity does not affect outcomes while learning a puzzle [18], we are not aware of prior work that indicates how partner familiarity and relationship type impact older adults' exploration of complex technologies, which is a promising direction for future work.

Our observations of some younger participants not trusting their older adult partner's opinions align with prior research that has identified older adults as "untapped resources", as the false assumption is that older adults cannot provide support regarding technology issues [31]. This phenomenon not only hurts the quality of communication in some mixed-age dyads, but also appeared to impede older adults' self-efficacy with respect to software exploration. In some cases, younger participants infused fear in older adults which led to the older adults seeking approval before performing actions. Unfortunately, this seemed to create a negative cycle: Some younger participants did not trust their older adult partners because of their inability to explore. This lack of trust led to patronizing language, which reduced their partner's independent exploration even further. We suspect this cycle can be broken if the younger generation attempts to use more supportive and encouraging language towards older adults [67], however, some younger partners might need more awareness of the implications of their reactions. Interestingly, in our study, we observed trust issues within same-age dyads as well, which potentially reflects internalized ageism [3,34].

5.2 Beyond Age: Salient Partner Characteristics

Initially we hypothesized that age differences might impact the quality of the collaboration between older adults and their learning partners. However, our results uncovered some nuances on this matter. Consistent with past investigations [34], we observed older adults preferring someone who knows more than them as a learning partner, but somewhat contrary to previous research [31,54], the age of the learning partner was less relevant. Their partner's experience and knowledge seemed more important, which could be misinterpreted as a preference towards younger partners due to younger people having more technology experience. However, our participants' interview responses were more nuanced than just wanting a partner who knows more. For example, older adults also worried about their ability to keep up with a learning partner who is much more knowledgeable and tech savvy, and being a burden on their partner. On the other hand, while our older adult participants appreciated a partner who was at their level because they knew the partner had similar limitations, they sometimes found it frustrating because they had to help their partners while they were struggling themselves. This might have been related to older adults' struggle to recover from interruption during tasks [51], making them less willing to pause to assist their partner.

The above two ends of a spectrum open interesting future research questions about the ideal partner for an older adult learning a new feature-rich application: is it better to have a partner who is far ahead in knowing the software or someone who only knows a bit more? For example, a learning partner who is just a few steps ahead might struggle to balance learning the software themselves and helping their partner. On the other hand, a very advanced partner might be in a better position to provide answers, but also less understanding and relatable.

5.3 Support Progress Checking/Error Testing to Enhance Exploration

We observed many older adult participants achieving substantial task success, and some even chose to continue working on their cottage designs while we interviewed their partner (see Fig. 8). Other older adults appeared to struggle with assessing their work and fixing mistakes and this appeared to limit how far they could get in exploring and learning the software. This issue is likely particularly prominent in CSTs, but could also be relevant to other feature-rich applications that involve complex multi-step tasks, for example trip planners, where the user has to test the impacts of their selections on other constraints. We observed that explicitly taking action to evaluate their work on complex tasks was not initially intuitive to participants, especially for older adults. Younger participants, on the other hand, tended to pick up on the idea of testing their work after reminders from the task instructions or the researcher. This aligns with a prior finding that older adults struggled in understanding system feedback while exploring a feature-rich software individually, which manifested as repeating unsuccessful series of actions [43].

Our findings go beyond prior work by identifying two primary challenges that older adults experienced related to task assessment and error testing that we did not observe with the younger participants. The first was difficulty navigating the application. While one might suspect these navigational difficulties are relevant to only the GT and GTM applications, some are generalizable to several feature-rich software learning situations. This is particularly true for older adults who lacked comfort in switching tabs and screens. The second difficulty we observed older adults having was related to not understanding how to assess their progress when visiting their cottages, which we suspect is largely related to them having little to no prior experience with similar software. Most of the younger participants were able to transfer their prior knowledge with similar software (such as games and graphics software) to GT and GTM.

5.4 Implications for Design

Our findings suggest several technology design implications for supporting older adults in exploring feature-rich software, both individually and with a learning partner. We acknowledge that our insights were derived from studying a single feature-rich software application; however, Gather.Town Mapmaker shares characteristics with other feature-rich applications (such as mulitple interaction modes and multiple views), which enabled us to formulate suggestions that might also be valuable for improving older adults' experience with learning other feature-rich applications. First, the different collaborative dynamics and differing levels of success has across those dynamics has interesting implications for systems that aim to match people with others for collaborative software learning experiences. For example, application expertise is one potentially important factor, but how the partners perceive each other's competencies and their assumptions about an older adult's capabilities may also be salient factors in partner matching.

Additionally, our findings suggest opportunities for system designers to consider ways to communicate partner competencies both before a match is made and during the partnership. For the latter, systems that have a notion of task progress could display task steps completed so that the learning partner can see if their partner is ahead and therefore in a position to provide help. When partners are working on a task not known to the system, there might be opportunities to display command usage information for task-agnostic "over-the-shoulder" learning [28].

One of the obstacles we identified was the high number of steps required by users to assess progress, which was challenging for some of the older adults in our study. This obstacle could potentially be lessened with easier ways to test output, such as through easy-to-access preview modes. We also observed older adults having more difficulty leveraging their prior software experiences given that they had less familiarity with 2D spatial applications than their younger partners. Prior work has proposed techniques to help users with transfer learning in feature-rich software [36,58]. Our findings suggest value in pursuing personalized approaches that adapt to user's existing familiarity with different types of applications. One way to address this would be having feature-rich software advertising indicate the pre-requisite skills needed to get started. The challenge, however, would be to avoid discouraging older adults who do not have the pre-requisite skills. Therefore, one might consider tutorials targeting the necessary skills and domain knowledge to help older adults become familiar and comfortable enough to start collaboratively learning the feature-rich software.

Finally, there is a wide body of work on providing users with in-context help, including social mechanisms that involve other software users (e.g., [13,37]). One interesting question is if this content could be tailored to older adults' needs. For example, might older adults benefit more from explanations and demonstrations from other older adults, as a way of increasing relatedness and acting as a form of encouragement? This type of social support from other older adults was shown to be effective for simple IT skill learning [42], but has not been investigated in the context of complex tasks within feature-rich software.

5.5 Limitations

While choosing GTM allowed us to investigate older adults' experience of learning feature-rich software as opposed to simpler types of technology such as IT/ICT applications, it is only one type of feature-rich software. Certain aspects of GTM, such as different modes, complex dialog boxes, and multiple layering, share similarities with other types of feature-rich software like graphic design tools (e.g., Photoshop). However, GTM also incorporates unique features, such as the ability to assess design progress by entering the designed space in GT. In other words, evaluating design progress in GTM requires spatial navigation, which may not be applicable to other feature-rich applications. Thus, future studies should verify the generalizability of our results with other types of feature-rich software. Also, our two-session study only briefly introduced participants to GT and GTM before asking them to engage in a variety of map design tasks ranging from simple to complex. A longitudinal study could generate different results by allowing participants to practice some simpler tasks over time to gain more familiarity with a feature-rich application before attempting more complex tasks with a collaborative partner.

While our observational study allowed us to document collaboration dynamics and exploration challenges, we were limited in our ability to measure the effectiveness of collaborative learning beyond assessing individual performance on a single task [21]. Future longitudinal studies are needed to investigate how different dynamics might impact longer-term software learning experiences. Future studies should also investigate the generalizability of our findings to different collaboration scenarios. For example, in our study, the learning partners were remote. While many older adults are remote from potential learning partners, the challenges of remote communication (e.g., viewing each other’s screens) introduced communication difficulties that would not be an issue in a co-located setting.

In our study, the researcher provided assistance when the participants were unable to progress, to avoid participants becoming overly frustrated. While we had consistent rules for when to provide this assistance, in the end, the amount of assistance provided varied according to the difficulties that participants experienced. The presence of the researcher might also have affected participants’ behaviour as they might have felt that they were being watched or judged by an expert. Future research should consider ways to reduce researcher presence, which would remove this potential confound. However, it is important to acknowledge that such an approach may introduce tradeoffs. For instance, while assigning easier tasks could decrease the researchers' involvement, it could also result in fewer learning opportunities for certain pairs. Additionally, opting for a field study that minimizes the researcher's presence may offer a more natural setting, but it would likely preclude detailed interaction analysis.

Finally, we had a relatively small number of participants, which led to a small number of each type of dyad. A study with a greater number of participants would help to achieve a more robust understanding of the collaboration dynamics that we detected. Also, the diversity of our participants was limited as one of the main recruitment sources used was through universities’ retiree associations, which led to us having a well-educated pool of older adult participants. Less educated older adults may have different experiences with collaborative learning of feature-rich software.

6 CONCLUSIONS

To make the exploration of feature-rich applications a more pleasant and effective experience for older adults, we examined collaborative learning, which prior research suggested as a promising approach in the context of learning basic IT/ICT skills and video games. We observed the interactions of mixed-age and same-age dyads while exploring a new feature-rich application for the first time. By comparing the distinct attributes of four different collaboration dynamics that emerged between learning partners, we found that effective communication and confidence to navigate and explore independently contributed to successful collaborations. Our results demonstrated that trust between partners was a main driver of effective communication and influenced the exploration behaviours of older adults. Also, we found that progress checking or error testing, which is a common process when engaging in complex tasks using feature-rich software, was particularly challenging for older adults. We found that partner age was not a predictor of successful collaboration, and future work in this area could explicitly compare and investigate other partner characteristics, such as the relationship between partners and their level of expertise with similar types of software.

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