An Interactive, Unplugged Activity to Engage Children in Designing Solutions for Smart Villages

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Abstract: Smart villages require the involvement of residents. However, past experiences have revealed that goals were often not achieved because the community was treated as a single entity. In particular, the literature highlights the importance of improving smart services and outcomes to meet the needs of children, who are often excluded from participatory initiatives and rarely recognized as stakeholders. Non-conventional learning environments, like science festivals, provide an excellent opportunity to raise awareness and engage children as stakeholders in smart villages. However, organizing these events can be challenging due to the diverse backgrounds and varying needs of participants. Moreover, organizers often lack familiarity with individuals' learning styles and requirements. This study presents an interactive, unplugged activity aimed at children aged 6 to 10, where they can devise solutions for smart villages while learning fundamental programming concepts. To illustrate the potential of this activity, we present the results of its initial implementation with approximately 100 participants during a science festival. The first results show that the proposed activity is effective, engaging, and inclusive, making it an effective method for managing large and diverse groups of participants at science festivals.

1 INTRODUCTION

Smart villages aim to implement the concept of smart cities in rural areas, drawing from research on smart cities (Dassori et al., 2019; Visvizi and Lytras, 2018). Just as citizens are integral to smart cities (Hennig, 2014), local participation is crucial for smart villages (Juan and Mceldowney, 2021). However, the experience of smart cities has revealed that goals were often unmet due to the oversight of the specific needs of their residents (Dameri, 2014). Furthermore, participatory planning processes have been criticized for considering an "average citizen" (Montalvan Castilla and Riel Müller, 2024). For instance, despite being beneficiaries, users, and data subjects (Sun, 2023), children have rarely been considered stakeholders (Montalvan Castilla and Riel Müller, 2024). They are often seen as passive users (Geeng and Roesner, 2019), and technologies are not designed with children in mind (Sun, 2023).

Non-conventional learning experiences, like science festivals, provide excellent opportunities to raise awareness and involve children in expressing their preferences for features they would like to see in smart villages. Diversity and heterogeneity are key factors of these initiatives (Fronza and Pahl, 2019) as they attract large and diverse groups of participants with different needs and backgrounds. Therefore, unlike in a traditional classroom setting, instructors typically do not know each participant's learning style and needs. This makes it difficult to facilitate these events, and there is a risk that participants may struggle to keep up with the pace of the activities and be dissatisfied with their outcomes (Fronza and Pahl, 2019). For this reason, inclusive educational material is needed for this particular setting. According to the cognitive load theory (Sweller, 1988), the material should be designed to reduce the extraneous load, which is caused by the complexity of the instructional materials, and focus on the germane load, which is devoted to the processing, construction, and automation of schemes in long-term memory (Ericson et al., 2018) to allow for the construction of schemes.

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Picking up from that need, in this paper, we present an interactive, unplugged activity to engage children aged 6 to 10 in designing solutions for smart villages, with a specific focus on smart homes. To foster algorithmic thinking education from an early age (Fronza et al., 2014; Djurdjevic-Pahl et al., 2017), the activity incorporates fundamental programming concepts to assist in managing various conditions within a smart home. To illustrate the potential of our approach, we present the results of its first implementation by summarizing them to analyze two relevant aspects:

1. Understand whether the proposed interactive, unplugged activity succeeds in involving children in designing solutions for smart homes.
2. Outline the effectiveness of the proposed interactive, unplugged activity for science festivals targeting younger children.

According to the results of the initial implementation, our approach was successful and allowed us to manage large and diverse groups of participants inclusively. At the end of the activity, the participants demonstrated their understanding of the *if-then-else* construct and effectively acted as stakeholders by expressing their desired features for smart homes.

The rest of the paper is organized as follows. Section 2 provides background information and related work. Section 3 describes the proposed interactive activity. Section 4 describes the first evaluation of the proposed activity and Section 5 reports its results. Section 6 concludes this work.

2 BACKGROUND INFORMATION AND RELATED WORK

Smart villages face the typical issues of rural areas (Zavratnik et al., 2020), such as limited access to essential services like healthcare and education, low digital literacy, and fewer job opportunities (Johnson and Lichter, 2019; Cunha et al., 2020; Anastasiou et al., 2021; Rodríguez-Soler et al., 2020). Moreover, the rapid adoption of new technologies tends to occur in urban areas, further widening the digital divide (Stojanova et al., 2021).

Smart homes consist of interconnected sensors, interfaces, devices, and appliances, enabling automation and local or remote control of lighting, ventilation, heating, energy usage, and security (Paetz et al., 2012). These homes collect contextual data about the environment and their residents to offer customized support and user-friendly interfaces, prioritizing the user's perspective (Singh et al., 2014). However, smart homes are often designed by considering children as passive users (Geeng and Roesner, 2019; Sun, 2023).

To address this issue, it is necessary to involve children more in designing solutions for smart homes by considering them as equal stakeholders and valuing their input as experts in their own lives (Hansen, 2017). For instance, Sheriff et al. developed a mechanical tool for children that encourages systematic exploration of mechanical concepts, initiative, procedural thinking, and positive risk-taking in a home environment (Sheriff et al., 2017). Another study proposed a user interface designed for children to help them describe tasks related to end-user development in smart homes. An experiment involving 32 participants aged 8 to 12 was conducted in a simulated classroom designed to resemble a smart home to evaluate the effectiveness of this user interface (Kakavand et al., 2023). Berrezueta-Guzman et al. developed a smart home environment designed to assist children with their daily tasks (Berrezueta-Guzman et al., 2020). This environment incorporates intelligent objects, such as study chairs and desks, which monitor children's behavior during homework and provide real-time supervision and guidance. In interviews with 17 children aged 9 to 12, it was found that they strongly associated smart home technologies with practical needs, such as cleaning their rooms or turning on lights (Erel et al., 2020).

The effort to engage children in the co-design of urban environments has largely focused on the context of smart cities. Gomes et al. introduced the Smart City Kids Lab project aimed at encouraging children to explore and learn programming (Gomes et al., 2019). Simonofski et al. developed a participatory design workshop aimed at enhancing children's understanding of the smart city concepts (Simonofski et al., 2019). This workshop comprised three parts: a theoretical introduction, the creation of a smart city model, and the identification and resolution of urban challenges within that model. The smart city model developed during the second part of the workshop relied on paper, which made it difficult for the children to engage in meaningful discussions. To address this issue, Clarinval et al. proposed a collaborative, tangible interface (Clarinval et al., 2021). Their updated city model featured an interactive table that displayed a blank city map. In 2023, Clarinval et al. proposed a workshop aimed at educating children aged 12-14 about smart city concepts. The workshop involved participants in exercises related to urban planning and aimed to develop a method for citizen participation. However, one limitation of the workshop was that the children completed the post-test several days or weeks later (Clarinval et al., 2023).

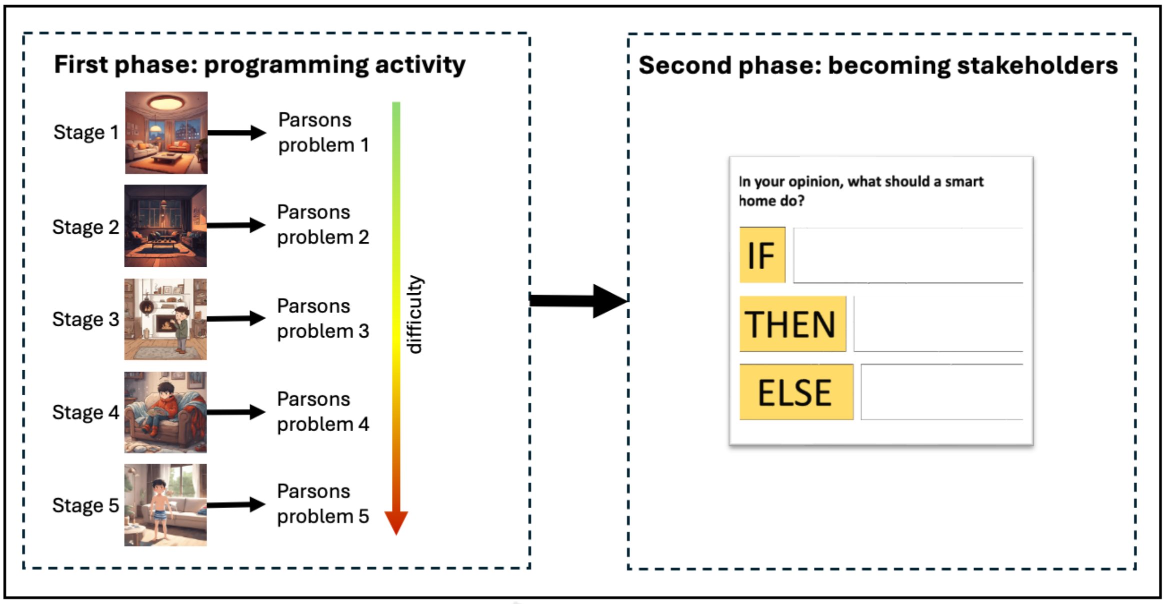


Figure 1: Structure of the activity. All the images representing the stages are AI-generated.

3 THE INTERACTIVE, UNPLUGGED ACTIVITY

The proposed activity engages children in designing solutions for smart homes. As shown in Figure 1, it consists of two phases detailed in this section.

3.1 First Phase: Programming Activity

In this phase, children are introduced to the concept of smart homes through an unplugged programming activity. While completing this phase, children learn the basic programming construct for managing different conditions in smart homes, specifically the *if-then-else* construct.

Table 1 summarizes the five stages of the unplugged programming activity. Each stage corresponds to a situation that can occur in a smart home. Each situation is illustrated in an image to help children understand them more easily. In each stage, children are required to write instructions for programming the smart home using the *if-then-else construct*. Children must complete one stage before moving on to the next.

To program the smart home according to the given situation in each stage, children solve *Parsons problems* by correctly rearranging the solution's lines of code presented in a scrambled order as colored tiles (Ericson et al., 2022). The main characteristics of Parsons problems are implemented in each stage as detailed in Table 2.

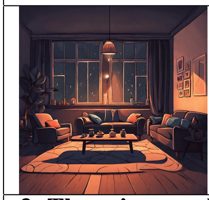
The Parsons problems present increasing challenges across the five stages. For example, in the second stage, the secondary execution path is introduced when the *if* clause evaluates to false. From the third stage onward, distractors are added, first one and then two, which increases the number of tiles to consider while writing an instruction.

The choice to incorporate Parsons problems originates from our objective to create an interactive and inclusive learning activity suitable for non-conventional educational settings. Specifically, we use *adaptive* Parsons problems to improve teaching and support learning (Ericson et al., 2018; Hou et al., 2022; Prather et al., 2023; Wu and Ericson, 2024) of students with special educational needs or cognitive impairments (Haynes, 2020; Haynes-Magyar, 2024).

We utilized two distinct approaches for implementing adaptation in Parsons problems. *Intra-problem adaptation* is obtained by having the instructor dynamically make the problem easier if the learner is struggling to solve the problem. *Inter-problem adaptation* is obtained by having the instructor modify the next stage based on the learner's performance on the previous one (e.g., by skipping one stage). Being an unplugged programming activity, the instructor provides immediate line-based feedback on the solution (Ericson et al., 2022) and answers to potential questions.

Children progress through the five stages at their own pace and can seek support from the instructor whenever needed.

Table 1: The five stages of the interactive activity. Each stage corresponds to different situations that can occur in a smart home.

Stage	Fragments	Solution	Characteristics
1. Nobody is at home			
	if then turn it off the living room light remained on	if the living room light remained on then turn it off	There is no secondary path of execution when the "if" clause evaluates to false. There are no distractors.
2. It is dark in the house			
	if then else raise the roller shutter turn on the light it is daytime	if it is daytime then raise the roller shutter else turn on the light	There is a secondary path of execution when the "if" clause evaluates to false. There are no distractors.
3. There is a smell in the house			
	if then else open the window fully it is not raining outside and its not too cold open the window a bit spray deodorant	if it is not raining outside and its not too cold then open the window fully else open the window a bit	There is a secondary path of execution when the "if" clause evaluates to false. There is one distractor.
4. It is winter and it is cold at home			
	if then else turn on the heating the window is open close the window fully turn on the tv prepare hot chocolate	if the window is open then close the window fully else turn on the heating	There is a secondary path of execution when the "if" clause evaluates to false. There are two distractors (easily identifiable).
5. It is summer and it is hot at home			
	if then else sunlight streams through the window activate the alarm turn on the air conditioner close the curtains open the refrigerator	if sunlight streams through the window then close the curtains else turn on the air conditioner	There is a secondary path of execution when the "if" clause evaluates to false. There are two distractors (more difficult to identify respect to the previous stage).

All the images representing the stages are AI-generated.

3.2 Second Phase: Becoming Stakeholders

In the second phase, children take on the role of stakeholders and share their opinions on the features they want to see in a smart home. To this end, they are encouraged to answer the question: *In your opinion, what should a smart home do?* by using a card that reflects the structure of the five stages they have completed in the first phase of the activity.

As shown in Figure 1, the card has three blocks labeled *if*, *then*, and *else*, and three empty blocks to be completed with a condition, the action to be performed if the condition is true, and the action to be performed otherwise.

4 FIRST IMPLEMENTATION

To illustrate the potential of the proposed activity, we implemented it at a public science festival in Bolzano, Italy. This festival is a free-to-attend family science day featuring talks, demonstrations, exhibitions, and interactive experiences on Science, Technology, Engi-

Table 2: Characteristics of Parsons problem (as listed in (Ericson et al., 2022)) in the proposed activity.

Characteristic	Motivation
Atomicity	A limited number of fragments is provided. Fragments are elements of a line.
Problem Space	The number of available fragments is limited and reuse is not allowed. Distractors are introduced in the more advanced stages.
Constructing a Solution	Each stage begins with an empty solution space into which the fragments are positioned in order.
Correctness and Feedback	The instructor provides immediate line-based feedback on the solution.
Modality and User Interface	A drag-and-drop environment is simulated: fragments are written on colored tiles. Yellow tiles contain the if-then-else construct.
Syntax	Fragments are written in natural language.
Scaffolding	Children can ask for the instructor's help.
Fit and Expected Time on Task	The presented problems are appropriate to children aged 6 to 10. Solving a problem requires 2-3 minutes.

neering, Art, and Math (STEAM) to encourage young people to pursue science education (Canovan, 2019; DeWitt et al., 2016). The festival provides an appropriate context for our interactive activity as it attracts a broad, non-expert, curious, and motivated to learn population. The festival involved around 2000 participants of all ages.

The proposed activity took place in a room with free entrance and no reservation required. Three workstations were set up on a large table, each with a chair, and three instructors (i.e., authors of this paper) were ready to welcome the participants (Figure 2). Children could approach the table spontaneously or be kindly invited by the instructors. They could leave at any point without completing all the activities. The booth was open for 8 hours and hosted approximately one hundred children (6-10 years old). The instructors collected semi-structured observations and the cards completed by children in the second phase.

Figure 2: Picture taken during the first implementation of the activity at the science festival.

5 RESULTS

In this section, we summarize the results of the first implementation of the proposed activity to analyze two relevant aspects.

1. Understand Whether the Proposed Unplugged, Interactive Activity Succeeds in Involving Children in Designing Solutions for Smart Homes.

Around 100 children participated in the first phase of the proposed activity, with a good balance of genders. Some children only completed part of the initial phase, mainly because they preferred to explore more booths at the science festival rather than spending too much time on a single activity. During this time, younger and absolute beginners typically completed two or three stages, while older and more experienced participants managed to complete all stages in around 15 minutes.

Overall, most children were eager to complete the stages before moving to the next booth and showed enthusiasm when demonstrating their solutions. Around 60 children completed the first phase. Some asked the facilitators for additional details and imagined other scenarios involving smart homes.

The observations collected during the implementation of the first phase are summarized in Table 3.

Table 3: First phase of the activity: results of the first implementation.

Observation	Result
Number of participants	~ 100
Min. time spent on the activity	10 min.
Min. number of stages completed	2
Max. time spent to complete all the stages	15 min.
Number of participants who completed all the stages	60

Out of the children who completed the first phase of the activity, only 18 went on to finish the second phase, in which they expressed their wishes for a feature in a smart home. The other children chose instead to engage in various other activities offered at the science festival.

The analysis of the completed cards reveals that all the children understood the fundamentals of the *if-then-else* construct, as they demonstrated their ability to input in the card a condition, the action to be executed if the condition is true, and the action to be executed otherwise.

Most of the 18 respondents understood the smart home's basic concept. Only three children mentioned a condition related to themselves rather than the house (for example, "if I am sleeping") and one also mentioned actions unrelated to the house ("if I am bored, then I jump, else I draw"). Confirming the previous literature in the field (Erel et al., 2020), children have shown a strong association between smart home technologies and practical needs. Among their desired features for smart homes, they listed the possibility of controlling shutters/windows, lights, cleaning, heating/air conditioning, and protecting from thieves/fires.

Table 4: Second phase of the activity: results of the first implementation.

Observation	Result
Number of participants	18
Number of children who understood the fundamentals of the *if-then-else* construct	18
Number of children who understood the smart home's basic concept	14

Overall, according to the observations collected in the first implementation, the proposed activity results as a successful means to inclusively involving children to whatever extent they chose to participate.

2. Outline the Effectiveness of the Proposed Unplugged, Interactive Activity for Science Festivals Targeting Younger Children.

The proposed activity was successful, engaging approximately 100 children of different genders in the target age of 6 to 10 years old, during the science festival. Additionally, the activity provided an additional opportunity to raise awareness about smart homes: while the children were busy with the activity, accompanying adults watched a video on smart homes that was projected near the activity table. Afterward, many adults approached the facilitators, who are experts in the field, to ask questions regarding smart homes and their controls.

The activity was inclusive, allowing all children to participate to some degree. We did not observe any cases of children immediately abandoning the activity. Moreover, all the children completed some stages of the first phase of the activity, with more experienced or faster participants implementing all the stages and even imagining additional situations in smart homes. Therefore, the Parsons problem structure has proven essential in involving everyone, at least in the initial and most straightforward part.

Most children had unconsciously decided to spend a maximum of 10 minutes on the activity. After this time, they preferred to move on and visit other festival booths. Only 18 children chose to continue to the second phase, which likely needed to be more engaging and playful to retain children's attention at the booth. After finishing the first phase, many children believed they were done and opted to spend their time at other booths instead.

These results suggest that this activity is effective for science festivals focused on younger children, as it not only captures their interest but also promotes inclusivity.

6 CONCLUSION AND FUTURE WORK

In this work, we presented an interactive, unplugged activity aimed at engaging children aged 6 to 10 in designing solutions for smart villages, with a specific focus on smart homes. The activity also incorporates basic programming concepts to help manage various conditions within a smart home. To illustrate the potential of our approach, we presented the results of its first implementation involving around 100 participants during a science festival.

The results from its first implementation show that the proposed activity is both engaging and inclusive. This makes it an effective method for managing large and diverse groups of participants, particularly at science festivals aimed at younger children. Moreover, the children who completed both the phases of the activity demonstrated their understanding of the *if-then-else* construct and successfully acted as stakeholders by expressing their desired features for smart homes.

Some limitations could impact the results of this work. For example, we have noticed that, consistent with previous literature in the field (Erel et al., 2020), children associated smart home technologies with practical needs. However, this may be influenced by the specific contexts presented in the first phase of the activity. Furthermore, conducting the study in an uncontrolled environment means we lack detailed information regarding participants' programming and smart home skills, which prevents us from confidently asserting that the activity contributes to developing these skills.

Replications are necessary to draw more robust conclusions, such as by conducting the activity in different non-traditional learning environments. Additionally, we need replications in more controlled settings to account for specific factors, including the presence of special educational needs. This level of control is not possible at events like science festivals, where we can only assume that participants have diverse learning needs.

Future work may consider transitioning from an unplugged version of the proposed activity to a more interactive digital tool, which could increase the adaptation of the Parsons problems in the first phase. Moreover, the second phase could address the issues identified in this work, specifically becoming more engaging. For example, children may suggest features they would like in smart homes by modifying a smart home simulation incorporated into the tool. Furthermore, the tool could use artificial intelligence to generate personalized and adaptive Parsons problems (del Carpio Gutierrez et al., 2024) rather than just learning to solve them (Hou et al., 2024), tailoring them to each child's cognitive needs. Finally, to better prepare the population for smart villages, the approach presented in this paper could be expanded to other disciplines beyond computer science, including non-technical fields.

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