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Programming-RIO: Initiating Individuals into Computational Thinking using Real-world IoT Objects

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Abstract: The paper aims at developing a better understanding of how interactions with the platforms like IFTTT or Alexa Routines that help in configuring complex if-then-else behaviors of real-world Internet-of-Things Objects (RIO) can help in supporting students' learning of computational thinking (CT). We call these platforms "Programing-RIO platforms". We aim at devising pedagogies around these platforms and the IoT devices to introduce CT to the novice students. With the broader research objective of exploring the impact of Programming-RIO on participants' problem solving with computational tools, our specific research objective is to explore participants' computational problem-solving process when they design automation solutions using IoT objects in the real world, using platforms like IFTTT, Google Home app, and Alexa app. Embodied narratives of computational thinking illustrated by the learner's entangled actions and thought processes during the pilot study have been presented in an effort to initiate the learners into computational thinking.

Keywords: Computational thinking, IoT, authentic learning, embodied, 4E cognition

1. Introduction

The question of 'how to effectively teach CT at an introductory level to enable learners in order to automate abstractions with ease' has fascinated scientists since before computers started to become ubiquitous. The terms 'CT' and 'computation culture' were first coined by Papert, (2020) in MINDSTORMS's first edition in 1980's which initiated early age learners into the world of computational creations with concepts related to procedurality. He also advocated that true 'computer literacy' is not just knowing how to make use of computers and computational ideas, it is knowing when it is appropriate to do so in a sociocultural context. Every educational advent then onwards corresponded to contemporary ways of teaching CT, e.g., agent based models, simulations, games, robotics, mobiles, IoT and everyday objects.

One of the major challenges in learning computational thinking (CT) is its associated abstractness of the concepts and procedures. Visual programming environments, such as scratch, NetLogo, Greenfoot, etc., attempted to reduce the abstractness by replacing the abstract textual representations (syntax) of the constructs with visual block-like elements. These visual programming environments have been proven to be significantly effective in training students' CT skills (Brennan & Resnick, 2012). A similar approach has been seen in using visual programming by Bers, Marina Umaschi, et al. (2014) for working with robots. Programmable robots-based learning activities reduce syntax's abstractness by employing visual programming environments similar to NetLogo and Scratch (Kim & Jeon, 2007) to program their robots. The fact that the robots are physical and tangible, and students can systematically manipulate them through coding, further bridges the gap between abstract CT constructs and reality. However, programmable robots have limitations in terms of the problem-solving contexts they offer, i.e., most programmable robots-based activities employ abstract and imaginary scenarios and lack authentic real-life problem contexts (Bers, Marina Umaschi, et al. (2014)). Programming the robot itself when tested as a way of teaching CT, is designed through a technocentric lens (Sengupta, P., 2018) where considerable time needs to be spent in the learning curve of the technology. It should be noted that learning while being situated in authentic real-life scenarios has been argued as a better learning practice by various literature of cognitive science such as situated learning theory (Lave, J., & Wenger, E., 1991) and constructionists approach (Harel, I. E., & Papert, S. E. (1991).

One other technology that has seen a sharp growth is consumer-level IoT (i.e., Internet-of-Things) devices which are becoming easy to use day by day. We propose the use of IoT devices and associated utility platforms to design learning activities that can help students practice CT constructs. Utility platforms such as IFTTT, Google Home, Alexa, etc. help in configuring the diverse IoT devices to work together and allow customizations based on the user's authentic problem solving needs. Examples of possible student tasks are given below.

Example: *Students are given a task to configure a smart light-bulb such that it automatically switches on at the start of the evening and switches off before sunrise.*

In the above example, the task of configuring the IoT devices, similar to the programming activities, will require students to apply CT skills to accomplish the needed behaviors from the IoT objects. In this paper, we propose to exploit such affordances of the IoT objects and the utility platforms to make entry-level CT learners practice various CT constructs by programming various Real-life IOT devices. We have termed such an approach as **Programming-RIOs**, where RIO stands for **Real-life IoT Objects**. These **RIOs** are slowly becoming ubiquitous in many parts of the world and society. Application of such platforms that are situated in the real world context (Lave, J., & Wenger, E., 1991) and have an impact on everyday life activities makes them more powerful as tools to think with to nurture CT skills.

2. 4E Cognition Accounts of Computational Thinking

Traditionally, the processes of thinking and reasoning are predominantly understood using the lens of information processing theories of cognition (Pande & Chandrasekharan, 2017; Reynders et al., 2020). These approaches assert that a problem solver first engages in the extraction of information from the content embedded in the learning or task environment (e.g. text, representations, tools, syntax, etc.); and then the learner performs thinking or reasoning about 'using' this extracted information. However, the new approaches to cognition (e.g. 4E cognition; Menary, 2010; Newen et al., 2018) and situated learning (Sentance & Humphreys, 2018)) insist that cognition and knowing cannot be separated from bodily actions and context. The embedded, embodied and enactive cognition approaches regard one's thinking and reasoning processes, actions, and the environmental elements being interacted with, as *entangled* together (Pande, 2020).

In summary, we hypothesize that these new approaches in cognitive science would also be applicable when analyzing one's computational thinking, and therefore the elements of technology-enhanced task environments and one's bodily actions on those elements should not be dissociated from CT, and are a part of their computational thinking processes. The situated learning and embodied cognition desirable for acquiring CT skills would also make room for alternate conceptions leading towards discoveries in real time, that add to the knowledge of either the technology or the CT practices for the learners.

3. Methodology

The study was an open-ended qualitative study designed to develop an initial understanding with the following broad research question in place: how do the participants respond to computational thinking tasks designed around Real-world IoT Objects? Do the activities and the RIO environment facilitate computational task execution for the learners?

The study is a pilot investigation which is a part of the Programming RIO for novices project. The participants were chosen using convenience sampling. There were two participants, one male and one female, (age 20 and 19 years respectively). They were second and third-year language (Sanskrit) undergraduates having no prior exposure to Computer Science in academics. These participants were chosen in order to know how adult learners who are novices to CT domain interact with the RIO environment and what could be the challenges they face. In-person sessions were conducted over a duration of approximately 3 hours. The session included a familiarization phase and an unguided problem-solving phase as shown in figure 1. The tasks in both these phases were aligned according to increasing order of complexity of the problem as described in the figure.

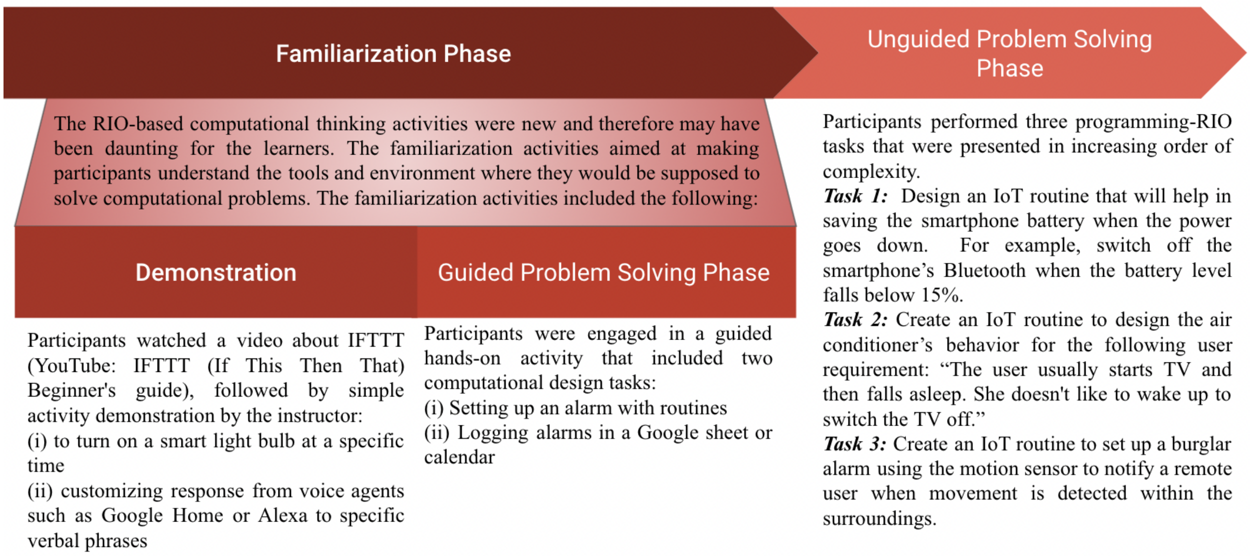

Figure 1. Phases of RIO project studies

Data Collection and Analysis

Semi-structured interviews were administered with the objective to make the participants retrospectively reflect on their problem-solving processes. The interviews attempted to be as non–leading as possible: with questions like *"can you narrate one of the activities, how you went about solving the problem in your own words"*. However, encouraging the students to be as detailed as possible (*"what made you feel that this service should be chosen first for this task?"*) tended to open up more information. Retrospective interviews were conducted towards the end of the study. The researcher also asked questions in between the two phases. In addition to the interview data, we also collected the video recording as observation data. Both the interview and video transcripts were analyzed to get a clearer picture of how the participants got familiar with the RIO environment and how they performed the given CT tasks.

Using the observation and interview data from our two cases we tried understanding how the participant's engagement with the tasks in the respective sessions may have triggered CT in the participants. We performed open and focused coding of the transcripts and got two themes of participants' engagements that correspond to different aspects of CT proficiency and problem-solving occurring in both the phases of the session. These themes are: Embodied narratives of participants developing familiarity with the computational tools; and (iii) Embodied narratives of participants developing familiarity with RIO-based CT. We describe these themes in the section below.

4. Results

4.1. Narratives Of RIO Based Computational Thinking: Familiarization with Computational Tools

During the demonstration phase, participants observed the instructor's actions and responses such as exploring interfaces of various RIO technologies, purpose and possibilities of environments, and finding required options. The process of inquiry is narrated through figure 2 in which the participant observes instructor’s actions in the app-interfaces.

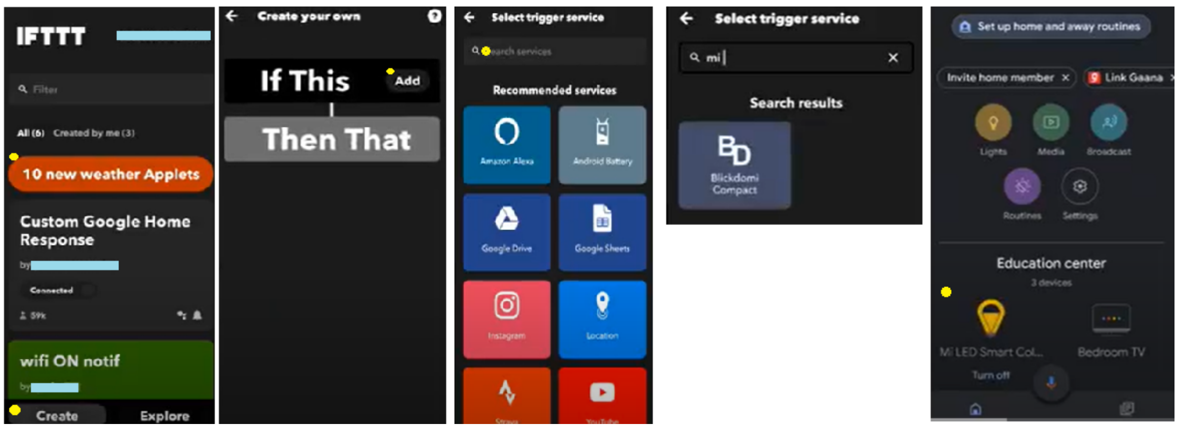

Figure 2. Sequential walkthrough of coding in demo activity - where instructor shows where to click (yellow dots) to the learner. On app-interface three, there is scrolling to view all the listed services, and when the intended service is not found ‘MI LED Smart Device’, they try to search in the text area. The demonstration ends with not being able to find the MI light bulb app on IFTTT, thus the decision of going for google home screen, eventually locating the desired application.

The participants' hands-on activities, they were seen quickly experimenting to programme routines in the app-interfaces suggested, but struggled to find the appropriate search keyword in order to find required services initially. Participants also encountered some system constraints in the first guided activity, such as responses from the Alexa and Google home mini ‘voice agents’ at irrelevant instances as the learners were trying to think out loud. Such an action-observation sequence made the participants consider the uncommon names for the procedures created by them.

The familiarization with tools was not just based on a single actions-observation sequence, but was seen to continue over a mixture of redundant action-observation iterations. For instance, in an unguided activity where the participant was to set an alarm, the participant tried to choose the alarm’s sound, adjusted the alarm’s times to distinguish the alarms from multiple app-interfaces and experimented with variables to observe the intended output. Such trial-and-test behaviour to observe the outcomes contained the decisions taken or interpretations negotiated by the learners.

4.2. Narratives of RIO based computational thinking: Solving a computational problem

Participants stated in their retrospective interviews post guided activity, that their environment allowed them to understand what to observe, e.g. specifically looking at a connected light bulb for an activity and then confirming the change in state of the bulb from real-world observation. The observation helped verify the accuracy of the procedure followed to change the state of the light, or it triggered the participant to revisit and revise the procedure.

In the unguided problem solving phase they frequently asked questions at the beginning such as, *“which app-interfaces should I begin with?”* The IFTTT app-interface shows recent connected applets designed by the users on a smartphone, the second participant reused an applet created by the previous user in the first task.

During the second unguided activity, the learner broke down the problem and solved it using two dependent if-then loop structures, where one part of the activity will turn on a timer after the sensed trigger of the television turning ON. The second part of this activity will have to turn off the television once the timer goes off after 10 minutes. In the retrospective interview, the participant used hand gestures while stating the if-then sequence by pointing towards the TV and then rolling hands in a half-circle to point towards the smartphone (timer). The recognition of two dependent sequences of activities and the tools involved within the activity prompted her to suggest that IFTTT services, where multiple actions can be added using the '+' sign on app-interface, might be used for this type of activity.

One of the discovery instances in the next activity was where the learner found a 'wait' option on the Alexa interface and connected it to the previous activity. The learner expressed that it could have been useful to add 'wait for 10 minutes' as a timer to turn the TV device off without any alarm or notification requirement. Here, we observe the iterative and entangled processes of actions, observations and thoughts involved in embodied cognition, as the learner has updated her knowledge with an application of the current observation relevant to solve the problem previously faced.

5. Discussion and Conclusion

During the retrospective interviews, it was found that the learners found the activity contexts easily relatable and transferable to their everyday life situations. This is important as according to Wing (2008), and Hu (2011) computational thinking is about identifying aspects of computation in our surroundings. This also could be explored further as a way to lessen the abstractness of imaginary scenarios for employing computational skills in problem solving, as with RIO tasks, the learners find authentic problem solving scenarios from daily life.

We found that the learning curves for getting familiarized with the smartphone app-interfaces were short, it could be because of their everyday use of smartphones. Some of the learning processes that may have contributed towards better clarity of the app features are the participant's interactions with the app-interfaces that lead to identification of constraints, verification of expected responses and discovery of the unexpected responses from the RIO tools (section 4.1). The trial and test behaviour of the participants to distinguish different service responses could be seen as a way to manage multiple layers of programming interfaces.

In the problem solving process, it was found that each participant can have different starting points for problem solving with RIO (section 4.2). they delved into connecting and managing multiple layers of abstraction by connecting the dots between an activity with the previous one's struggles. Instances such as one of the learner's body movements in order to express dependent behaviours in a complex problem's pieces reflect constructs in CT viz., abstraction and problem decomposition. Verification of programmed routines was seen as being aided by observability of the actions in real life which could be a sign of debugging or testing abilities useful in the problem solving process.

While debugging the activities, learners applied multisensory actions and observations while engaging with the problems. The data analysis in this pilot study presents an account of participants' (computational) problem solving mechanism, in the given RIO-based environment. The RIO-based environment included the utility platforms, i.e., the smartphone app-interfaces and the IoT objects in the physical lab space.

For the scope of this exploration, we have only tried to view the proposed RIO programming activities and tools as a task environment for initiation of authentic problem solving using CT and not as a learning environment for development of CT. We observed that the mechanism of problem solving included participant's (inter)actions with different elements of the environment, and changes in their mental models of the system, strategies, decisions, and actions based on different interactions. In our preliminary exploration it seems that RIO has the potential to engage and motivate learners in computational thinking situated in the physical and authentic environment. However, more studies are needed to better understand embedded and embodied accounts of how individuals solve computational problems in the RIO-based settings.

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