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FRACTOS: Learning to be a Better Learner by Building Fractions

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ABSTRACT

Real-world learning interactions happening in classrooms, often involve children interacting simultaneously with teachers and peer learners. FRACTOS is a triadic learning interaction system which is structured to emphasize the learner on different phases of self-regulation such as planning, performance and reflection while engaging in a constructionist task of building fractions using virtual LEGO blocks with a virtual tutor and robot peer.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; • **Applied computing** → **Interactive learning environments**; **Collaborative learning**; • **Computing methodologies** → *Intelligent agents.*

KEYWORDS

Child Agent Interaction, self-regulated learning, learning task, fractions, collaborative learning

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1 INTRODUCTION

Fractions are among the most complex mathematical concepts that children need to learn in their early years of education[6]. Several studies have reported the instructional difficulties and learner misconceptions[9] that challenge both researchers and scholars in teaching fractions. Fractions are considered as a multifaceted concept[3] that involves the following interrelated sub-constructs of part-whole, ratio, operator, quotient and measure. These sub-constructs have been identified to be relevant for various understandings on fraction such as fraction operations (such as addition, multiplication etc), fraction equivalence and problem-solving. Artificial pedagogical agents are increasingly being used to provide motivating, engaging and personalised learning support to learners[7], especially for teaching challenging concepts in mathematical and computational thinking[2].

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A review on research-based design of pedagogical agents[4] observed that agent roles with expertise such as expert or mentor have improved the learning outcomes while the motivator role had more influence over increased self-efficacy. Thus, a collaborative learning interaction involving multiple agent roles can potentially facilitate distinct regulation scaffolding. FRACTOS learning activity is thus designed around the foundational constructs of fractions and involves a virtual agent who portrays a realistic representation of a more knowledged entity capable of external regulation support such as tutor, while the robot agent, which shares the physical space with the child, acts as a peer learner facilitating co-regulation.

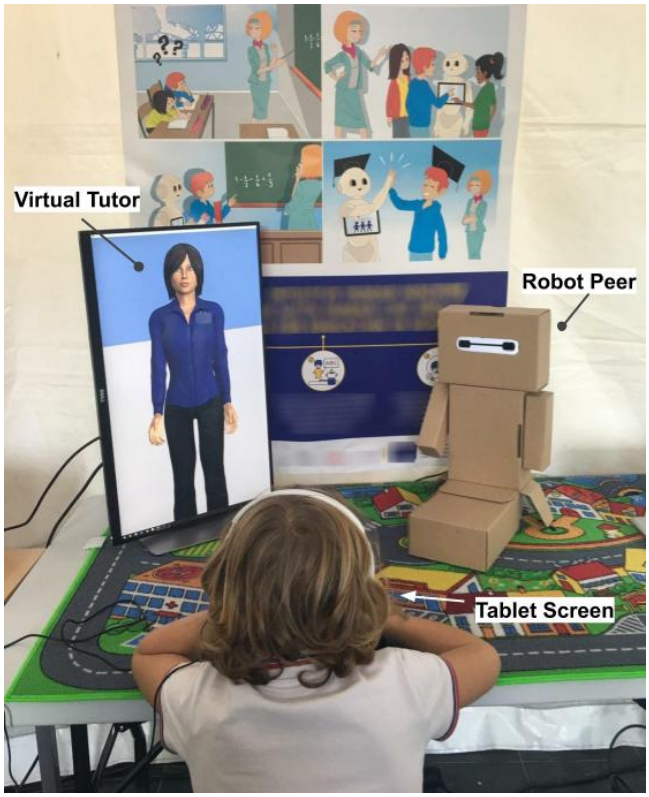


Figure 1: Pilot interaction of FRACTOS task

2 DESIGN AND IMPLEMENTATION

Regulation of learning[1] entails the processes of goal setting, monitoring progress, analyzing feedback, adjustment of goal-directed actions and/or of the definition of the goal. The proposed learning task targets children of age 7 to 11, who are in the concrete operational stage, according to Piaget's stages of cognitive development[11].

This age group is characterized by the development and consolidation of logical thinking as well as a decrease in egocentrism. This allows children to understand mathematical concepts and engage in activities that involve perspective-taking and proportional reasoning.

2.1 Framework

The FRACTOS framework is developed in Unity3d as tablet-based game which is played along with a virtual tutor and a robot peer both of which are partly controlled by a human wizard to make sure the interaction stays within the learning topic. The virtual agent and robotic agent are positioned on either sides of the activity space facing the learner at equal angles. The virtual tutor is modelled on GRETA[8], which is an Embodied Conversational Agent Platform equipped with socio-emotional and communicative behaviours such as gaze and gesture that enable designing various social attitudes for each role. The role of peer learner is played by an arduino-based humanoid robot called CardBot which was designed and developed for the activity as a scalable and affordable alternative for Wizard of Oz based HRI orchestrations. The actions of robot are animated and controlled from Unity3d by establishing a serial communication with Arduino using Uduino Unity plugin[10]. The speech of the robot is generated using the IBM Watson service and is modified later in Unity to sound like a child as it suits the role of a peer learner better. The system enables collecting the regulation behaviours of the child from the gaze behaviours and performance trace measures from the tablet such as error rate, response time, time for task completion etc during the activity and enables the wizard to trigger appropriate agent behaviours to promote regulation.

2.2 Game instance

The FRACTOS game consists of the tasks for building new fractions using the fundamental blocks of 1/2, 1/4 and 1/8. For instance, to build the fraction of 5/8, the child can chose to put together 5 blocks of 1/8. The virtual tutor agent facilitates external regulation through instructional behaviours while the robot peer is characterized by think aloud behaviours to promote co-regulation. The interaction starts with an introduction phase where both agents introduce themselves to the child by engaging in a small talk. Then starts the activity phase of 15 minutes involving 5 exercises of building fractions. Each fraction building task involves both agents exhibiting regulation behaviours during the three phases [12] of learning regulation as follows:

- Planning Phase: Verbalization or behaviour related to the selection of procedures necessary for performing the task which is done before starting to build the fraction.
  Tutor agent : You can use the red blocks to build this fraction.
  Peer agent: Which block shall we use for building 5/2 ? Red or green?
- Performance Phase: Verbalization or behaviour related to the ongoing on-task assessment and the degree to which performance is progressing towards a desired goal.
  Tutor agent : Try using the 1/2 blocks instead.
  Peer agent: Do you think 1/2 block is right one, my friend ?
- Reflection Phase: Verbalization or behaviour related to reviewing task performance and evaluating the quality of performance which is done after building the required fraction.
  Tutor agent : Now tell me, how many red blocks did you use for building this fraction?
  Peer agent: I think we took three 1/2 blocks to build 3/2. Am i correct, my friend ?

The FRACTOS game enables the wizard operator to advance through the interaction step by step and also return back to any specific instance in the interaction script if needed, for example when the learner is distracted from the activity(see Figure 2). The wizard interface is split into 3 parts:

- Activity monitor: Real-time monitoring of the tactile interactions which the child is performing on the tablet screen. This section also indicates error notification, accumulated error count and the current score of the learner in the task.
- Camera monitor: Real-time video feed from the camera facing the learner, along with the information on the gaze direction of the learner.
- Agent Controls: Includes triggers for pre-scripted or custom text inputs instantiated to multimodal behaviours for both agents, which can be triggered whenever needed by the wizard.

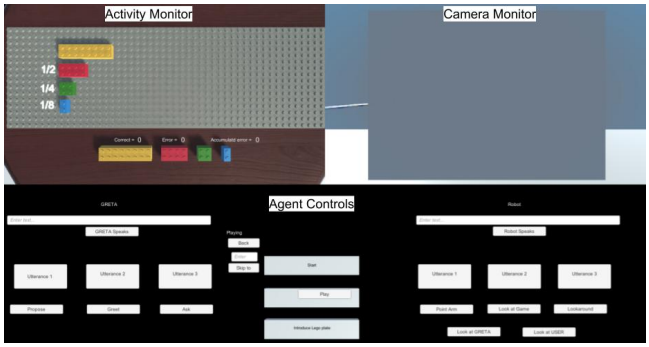


Figure 2: Wizard console for FRACTOS task

3 DISCUSSION AND FUTURE WORK

The FRACTOS learning task was showcased to public for a pilot interaction with 25 children between age 5 to 13 at a science festival(see Figure 1), which gathered positive feedback on agent perception and task engagement from children through questionnaires and also receiving appreciation from parents and teachers alike. The proposed research plans to conduct studies using the FRACTOS task in primary schools to explore the two key aspects of regulation scaffolding[5] which are the mode and the moment for regulation scaffolding.

4 ACKNOWLEDGEMENTS

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