Towards an Adaptive Regulation Scaffolding through Role-based Strategies

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ABSTRACT

Agents (virtual/physical) in a learning environment can be introduced in different roles, such as a tutor, mentor, motivator, expert, peer student etc. Each agent type brings an expertise, creating a unique social relationship with students. Depending on their role, agents have specific goals and beliefs, as well as attitudes towards the learners, thereby influencing different aspects of learning such as cognitive, affective and meta-cognitive processes in a learner. The proposed research will primarily investigate the meta-cognitive aspect of self-regulation in collaborative learning interactions and its variations with various scaffolding strategies based on agent roles. The learning interaction will be based on the socially shared regulation model of self regulation, which accommodates the social context of self regulated learning created by agents in multiples roles and behaviours. The objectives of this research will be to understand how various roles and behaviours of the agents would influence the self regulation skills of the learner and to design a role-based strategy selection model for regulation scaffolding, based on the behavioural, motivational and cognitive measures of the learning interaction.

CCS CONCEPTS

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

KEYWORDS

collaborative learning; self regulated learning; child-agent interaction; adaptive scaffolding

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1 INTRODUCTION

Collaboration[7] can be defined as a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem. Various kinds of task or non-task related social interactions such as argumentation, conflict resolution, rapport building, team orientation, mutual regulation involved in collaborative learning interactions are observed to be essential for ensuring effective learning outcomes. Computer supported collaborative learning environments have enabled interventions in the social processes during learning by the means of artificial pedagogical agents such as virtual agents or social robots and their roles and behaviours towards the learner. Collaborative groups can be considered as social systems consisting of multiple self-regulating individuals who must at the same time regulate together as a social entity[13]. 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. Regulated learning can be of four kinds, described as follows:

- Self Regulated Learning(SRL), where a student uses self-assessment, goal setting, and the selection and deployment of learning strategies to reach the learning goal.
- Externally Regulated Learning(ERL), which involves a human or virtual tutor prompting an individual learner to deploy key SRL processes during their learning, which may, in turn, enhance their SRL.
- Co-Regulated Learning(CoRL), involves a peer learner supporting and influencing each others regulation of learning, typically in an interdependent and reciprocal manner.
- Socially-shared regulated learning (SSRL), that involves multiple learners regulating themselves as a collective unit, using consensus building and negotiation to co-construct and make decisions about group task goals, definitions, beliefs, strategies, and knowledge.

In the context of collaborative learning, socially-shared regulation has emerged as the key factor as it considers regulation processes involved in groups of learners. Emerging empirical evidence suggests the effectiveness of SSRL based scaffolding support in collaborative learning. The results from a study[14] on the socio-emotional challenges involved in collaborative learning indicated the use of shared regulation in addition to self-regulation. Based on an empirical study involving 18 graduate students, working in collaborative teams over 8-week period,[11] observed that supporting fellow team members to successfully regulate their learning was significantly important in achieving team goals. Another study[10] on collaborative mathematical problem solving of dyads of high achieving pupils also suggested the use of socially shared metacognition as a relevant factor for the quality of problem solving and recommends its addition to the conceptual tools of learning research.

The proposed research will be thus based on the Socially-shared regulation model of learning regulation[9], which combines the foundational theories of self regulation, that were mostly centered on individual processes, with the social and interaction aspects of collaborative learning. The SSRL model consists of four loosely sequenced and recursively linked feedback loops[19] emerging during a collaborative learning interaction. During the first loop, groups negotiate and construct shared task perceptions based on internal and external task conditions. Through the second loop, groups set shared goals for the task and make plans about how to approach the task together. In the third loop, groups strategically coordinate their collaboration and monitor their progress. Based on this monitoring activity, the groups can change their task perceptions, goals, plans, or strategies in order to optimize their collective activity. Finally, in the fourth loop, groups evaluate and regulate for future performance.

2 RELATED WORK

Various studies involving agent roles[26] such as mentor, motivator, expert, peer, novice, tutor etc have reported to have improved learning outcomes by providing mainly cognitive, motivational and emotional support through adaptive scaffolding and individualised instructions to the learner, though less explorations were conducted on the aspect of meta-cognitive functions of learning,such as self-regulation. A computer-based teachable agent called Betty's Brain[17] explored the self-regulation patterns in learning through learning by teaching approach. Virtual pedagogical agent based systems such as AutoTutor[8], Atgentschool[24] and MetaTutor[3] utilized the method of prompting and feedback of learner's self-regulation during the learning. Only a few studies have been conducted with robotic agents on providing regulation scaffolding.[15] explored how a robotic tutor, prompting regulation strategies can improve the learning gain. But most of these systems relied on scaffolds at predetermined time intervals and thus compromised on providing a dynamic regulation support. This calls for the need for developing a system that can track the learner actions, infer the regulation needs and provide scaffolding support through partner agents in a collaborative learning interaction.

3 RESEARCH QUESTIONS

The proposed research will explore the cognitive and emotional aspects of regulation involved in a socially shared regulation based learning interaction, through the following research questions:

- RQ1: Does engaging in a learning interaction with self-regulated learning partners improve the self-regulation behaviours of the learner ?
- RQ2: Do various roles of agents influence the learner's regulation in different ways ?

4 DESIGNING THE LEARNING INTERACTION

Recommendations from research regarding the roles of pedagogical agents and its influence on the learning gain and agent perceptions suggest careful orchestration of learning interactions involving multiple agent roles. A review on research-based design of pedagogical agents[16] 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. The research objectives will be attained through a series of studies based on the multi-agent interaction consisting of a virtual agent, a robotic agent and a child learner, engaging in socially shared regulation activities through a learning task. The virtual agent will assume the role of a more knowledged entity capable of external regulation support such as mentor, motivator or expert, while the robot agent, that shares the physical space, will act as a peer learner facilitating co-regulation. This configuration is also analogous to the real world learning interactions happening in classrooms, which often involve the learners interacting simultaneously with teachers and peer learners.

4.1 Learning Topic

The learning interaction will be based on the mathematical concepts of fractions and proportional reasoning[6], focusing on the foundational constructs of part and whole and ratios for teaching the understanding of fractional equivalence. The proposed learning task thus targets children of age 7 to 11, who are in the concrete operational stage, according to Piaget's stages of cognitive development[28]. 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.

4.2 Apparatus

The design of the learning task and experiments demand the implementation of a triadic interaction(see Fig.1) consisting of a virtual agent, a robotic agent and a child learner engaging in socially shared regulation activities through a LEGO-based constructionist learning task on the mathematical concept of fractions and proportional reasoning(see Fig.2). The central component of the setup will be the activity space located right in-front of the learner where the entire manipulation of LEGO blocks is intended to happen. The activity space and the learner will be analyzed using camera vision during the entire activity. The camera will capture the visual trace data from the activity such as spatial arrangement, structural errors and modifications, visual attention on activity space and on both agents, task completion time, non-verbal behaviour of the learner etc. The virtual agent and robotic agent will be positioned on either sides of the activity space facing the learner at equal angles. The virtual agent will be modelled on GRETA[22], which is an Embodied Conversational Agent Platform equipped with socio-emotional and communicative behaviours such as gaze and gesture that enables designing various social attitudes for each role and a NAO robot will be used in the role of a peer learner. A tablet-based structured diary measurement[25] setup will be installed next to the activity space to collect responses from the learner at the end of each level during the activity.

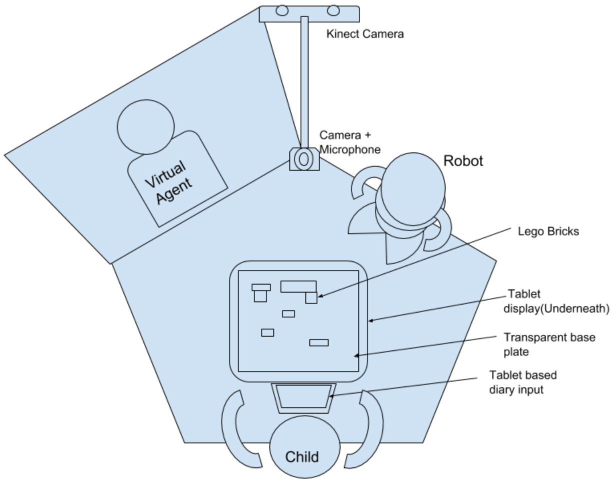

Figure 1: Illustration of the proposed triadic interaction setup involving the virtual agent, robot agent and the child learner, collaborating on a LEGO-based learning activity.

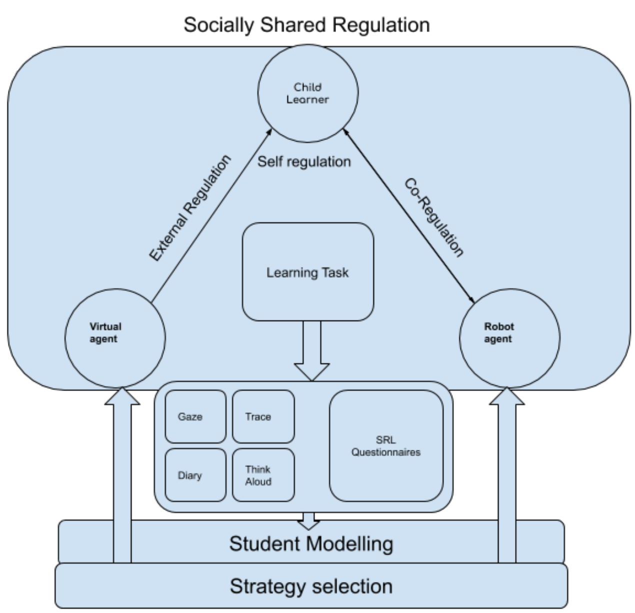

Figure 2: Elements of the proposed model for adaptive socially shared regulation scaffolding based on agent roles.

4.3 Measures

The proposed study setup aims to gather information about learner performance and engagement from the cognitive, meta-cognitive and behavioural signals through three potential categories of measurements, as follows:

- Gaze and head orientations[27]: The behavioural measures on the amount of attention paid by the learner to the partner agents and the activity space such as gaze and head orientations will be projected to estimate the quality and quantity of assistance anticipated from the partner agents. Behaviours such as smiling and maintaining eye contact are also indicators of engagement[5] used in child-agent interactions.
- Trace[2]: Traces refer to a record indicative of the actions and reactions exhibited by the learner during a task. The qualitative and quantitative measure of the activity space such as task completion time, structural accuracy, error occurrence rates, modification rates,etc will inform the contextual and cognitive states of the learner in real-time[23].
- Structured learning diaries and Think-Aloud measures[21] : Self-efficacy and self-regulation of the learner can potentially be measured using structured learning diaries and think-aloud protocols. These measures are considered efficient than SRL questionnaires and interviews, that often depends on factors such as language, response formats (rating scales), recall, etc. Recently developed tools such as OurPlanner[12] and RADAR[20] have utilized the instruments of learning diaries and think-aloud protocols for intervention and measurement of SRL.

5 PROPOSED STUDIES

In the given context of a collaborative learning activity involving multiple pedagogical agents playing the roles of mentor and peer learner, the scaffolding support emerging from each agent can have unique impacts on the learner's self and shared regulation of learning. The proposed research will focus on two key aspects of regulation scaffolding which are the mode and the moment for the scaffolding delivery. The mode of scaffolding would involve choosing the appropriate role based strategy for providing the support while the moment for scaffolding would determine how often the scaffolding is provided.

5.1 Mode of Scaffolding : SRL Instruction vs SRL Demonstration

The regulation strategies such as planning, monitoring, questioning, reflecting can be delivered directly or indirectly[18] to the learner by an agent in the environment. In case of a direct delivery, the scaffolding is often considered to be an external regulation originating from a knowledged source, capable of giving instructions. The scaffolding can also be indirect, utilizing the strategy of teaching by demonstration. The proposed Wizard of Oz study explores the impact of these two kinds of scaffolding support, during a learning interaction involving a child learner, a virtual mentor agent and a robotic peer learner agent. The study would compare two learning groups, one that involves a mentor agent instructing SRL strategies and the other which involves a peer agent demonstrating SRL strategies through actions and dialogue. Our specific hypotheses are as follows:

- H1: Instructional discourse of strategies would motivate performance oriented learning interactions in the learner.
- H2: Demonstration of strategies would motivate regulation oriented learning interactions in the learner.

The study will use the objective trace measures such as task completion time, error occurrence rates, number of voluntary trials by the learner etc during the task to measure the performance and regulation orientations. Structured diary inputs at the end of each level during the learning task would also ensure recording the perceived learning as well as the perception of the roles of agents by the learner. The results from this study will form the basis for designing the role-based regulation scaffolding system, capable of choosing between instructional and demonstrational modes for supporting the learner.

5.2 Moment for Scaffolding : Proactive vs Reactive Support

The scaffolding support can be provided either immediately when the learner is found to be in a difficulty or it can be given only when the learner demands support[4]. Delaying the support can potentially motivate the learner to engage in deeper SRL processes but it can also affect the self efficacy of the learner adversely if he/she struggles a lot during the activity. Thus, the time for providing the support is vital in ensuring learner's performance, motivation and regulation during the activity. The second study will be based on the following hypothesis:

- H3: Learners engage in better regulation processes when the scaffolding is reactive rather than provided proactively.

The proposed Wizard of Oz study will look at two learning groups, one that receives proactive support from the learning partners and the other in which the support is delayed till it is demanded by the learner. The results from this study are expected to inform about factors influencing the time for scaffolding delivery to maximize regulation and learning outcomes.

6 CONCLUSION

Altogether, the proposed research will produce a role-based regulation scaffolding model, capable of estimating the regulation state of the learner in real-time through various behavioural, cognitive and motivational measures and deploying appropriate regulation scaffolding strategies to improve the self-regulation skills of the learner as and when required.

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