Detecting patterns of Socially Shared Regulation of Learning in Smart Learning Environments

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Abstract. Smart Learning Environments are capable of adapting the learning experience of learners and providing personalized support based on individual needs and context. It is advisable that SLEs promote and support collaborative learning across physical and virtual spaces. Despite the well-known benefits of collaborative learning, there are many challenges that need to be addressed. The Socially Shared Regulation of Learning (SSRL) theory aims to understand the processes through which group members negotiate objectives, planning and strategies for carrying out a collaborative activity. Some studies on this topic have been conducted in face-to-face settings using students' self-reported or physiological data. Recently, regulation has been studied through traces of online platforms. However, SSRL has scarcely been explored with trace data nor in the multidimensional educational settings supported by SLEs. Consequently, this PhD thesis focuses on the problem of how to support collaboration by detecting patterns of SSRL using data coming from SLEs.

Keywords: Socially Shared Regulation of Learning, Collaborative Learning, Event-based data, Grounded LA in Learning Theory, Smart Learning Environments

1 Introduction and context

Smart Learning Environments (SLEs) are Technology-Enhanced Learning (TEL) environments capable of adapting the learning experience of learners and providing personalized support based on individual needs and context [4]. In addition, they might include features to promote engagement, effectiveness and efficiency, as well as support for struggling students, motivation or collaboration [15].

The ability to collaborate is one of the 21st Century skills [16] and is increasingly present in academic and work contexts [10]. Therefore, it is advisable that SLEs promote and support collaborative learning and include "social-awareness" among their characteristics [2]. Furthermore, SLEs can provide support for learning situations across physical and virtual environments, incorporating mobile phones or Internet of Things (IoT) devices [13], so they can offer many collaborative scenarios in formal and informal settings.

However, although collaboration has the potential to foster learning, research has shown that success in collaborative learning can occur when team members systematically activate and maintain their cognition, motivation and emotions towards achieving their shared goals [6]. There are numerous challenges while collaborating [8], that team members need to recognize, so that they can develop strategies to overcome them [10].

The Socially Shared Regulation of Learning (SSRL) [3] is a theoretical model that contributes to understand collaborative learning through shared regulation. SSRL takes place when team members negotiate the perception of tasks, objectives, planning and strategies. It has four stages that are linked and can be recursive: i) negotiation and construction of the perception of the task based on internal and external representations; ii) sharing of objectives and generation of plans to achieve them; iii) coordination and monitoring of progress; iv) reflection and redesign of objectives, planning or perception of activities.

Recently, regulation has been studied through Learning Analytics (LA) using traces offered by online environments [14]. These works show that study tactics and learning strategies can be detected from traces using machine learning techniques such as “process mining” [12] [5]. In addition, they show that students’ behavior changes over the course and suggest that such changes may occur due to regulatory processes. However, in order to know if these changes are produced by regulation, more information is needed on students’ motivation and intentions [5], as regulation requires reflection to make changes in behaviour to achieve the stated goals. To the best of our knowledge, the detection of regulation patterns using traces of online environments has started to be researched in the area of Self-Regulated Learning (SRL) but it has not been researched in the area of SSRL.

SLEs offer a good opportunity to do research in this direction, because they receive information from different learning environments and devices. In this way, they can potentially improve self-regulation [1] and socially shared regulation skills, as we expect to gain a more complete picture of the learning process.

2 Research questions and goals

The underlying research question of this doctoral thesis is: **How can we support collaboration by detecting patterns of SSRL using data coming from SLEs?** Our approach to answer this question is to automatically extract meaningful features from trace data and sensors based on the SSRL theoretical model.

The general objective (to support student groups to collaborate by detecting patterns of SSRL using SLEs data) is divided into three particular objectives:

1. **To map event-based data to SSRL theory constructs.**
According to [14], to achieve this objective we should first define a protocol that allows us to interpret and generalize the measurement method. We need to define a precise SSRL model where we can indicate the SSRL constructs or

phases that interest us. Then, we can define the phases or constructs at the event level. This mapping of traces to SSRL phases/constructs can allow us to identify important features to detect shared regulation patterns. Finally, we need to theorize how we can support collaboration using this model.

2. **To generate early predictive models of successful collaboration based on SSRL strategies.**
   We have to explore which machine learning techniques could detect SSRL patterns through the mapped data. Once we have achieved the above objective, we could identify which features can help us make early predictions.
3. **To design early interventions to support students' collaboration**
   Once we have theorized about how we could support collaboration (considering the teachers), we will have to design together with the teachers possible interventions to be done automatically according to the early predictions.

3 Brief state of the art

In order to answer the research question, the author is conducting a literature review on SRL and SSRL. In this section we are going to present some of the most important empirical works in these fields that have led us to motivate this thesis project.

In recent years, a number of empirical studies have been conducted in the area of SSRL. In particular, a learning environment with regulation tools was used in [10] to prompt students to recognize challenges that may hinder collaboration and to develop SSRL strategies to overcome them. This study employs students' self-reported answers to the questions asked in the virtual environment coded by the authors. The result of this study indicates that there is a difference between the regulatory processes followed by high and low performing groups. On the other hand, [9] studies the temporal and sequential order of the different types of regulation (self-regulation, co-regulation and socially shared regulation of learning) in collaborative activities. The data used in the study consist of videos of the working groups during two months in a math didactics course. Finally, in [7], a preliminary study uses data from different sources to help understand SSRL processes. Specifically, the use of physiological sensors is explored in greater depth, as is also detailed in [6].

These studies have been carried out with self-reported data or physiological data from students using invasive sensors. However, regulation can also be mapped to dynamic series of events that change over the learning situation [14] using traces from learning platforms. This approach has started to be researched in the area of Self-Regulated Learning (SRL) through process mining [12] but, to the best of our knowledge, it has not been researched in the area of SSRL and SLEs. As we mentioned above, since SLEs get information from different learning environments and devices, we can map these traces into SSRL phases to support socially-shared regulation skills, as we expect to gain a more complete picture of the learning process.

4 Methodology

The proposed methodology to answer the research question is Design Science Research Methodology (DSRM) [11]. DSRM aims at the creation and evaluation of artifacts that solve problems, like constructs, models or any designed object that offers a solution to the research problem. This methodology defines a process model involving the following phases: (i) identify a problem and motivate its interest; (ii) define the objectives of a solution; (iii) design and develop an artifact for the solution; (iv) demonstrate how the artifact solves the problem; (v) evaluate it; and (vi) communicate its performance. These phases do not need to happen necessarily sequentially. Indeed, refinements of the proposed solutions are foreseen by iteration of the different activities.

The overarching objectives of this thesis and its iterative nature make DSRM a suitable methodology to frame this thesis work. This PhD. thesis aims to design and develop artifacts that support collaboration by detecting patterns of SSRL using SLEs data. During the demonstration of the solutions, we will collaborate with the main stakeholders in order to: (i) carry out stable interventions during collaboration; and (ii) evaluate the degree in which the solutions meet the needs of the participants.

Regarding the number of iterations needed, we foresee three iterations. The first iteration consists on a literature review focusing on theoretical models and the adoption of these models in empirical studies to support students. This literature review is complemented with an exploration of the relevant collaborative scenarios in SLEs that can benefit from SSRL and the relevant data sources, machine learning techniques and actionable information to generate through SSRL. During the second iteration, the conceptual and technological solution to solve the detected gaps will be proposed and developed. Finally, the third iteration will focus on the evaluation and validation of the proposed solution.

5 Expected contributions

The contributions we hope to design and develop are intended to support collaboration in scenarios like the following one:

Jorge and Marta are Computer Science students. Collaboratively, they have to develop an application to manage musical events in their city following software design patterns. They have all the resources needed in Moodle: theoretical contents, practical exercises, video tutorials to install and use the necessary software...

Although they are very good students, they know that they will not be able to complete the project during face-to-face lectures and lab sessions, so they will have to work remotely as well. This is not a problem, since the teacher has asked them to work in a collaborative environment to program and generate the final report. The environment is Etherpad, which allows collaborative writing and offers to create audio and video sessions. In addition, during the lab sessions, the students groups will have a microphone at their table to record the spoken interactions they make.

Prior to this situation, the teacher had launched her SLE and had deployed the Learning Design of the subject. At this point, the SLE knew that it had to monitor the different environments (Moodle and Etherpad) and obtain different types of data from them (traces, video and audio).

Once Jorge and Marta start working together, the SLE is ready to process the actions they are performing and discover the study tactics they are using to develop the application.

At some point, the SLE detects that both students are in a bottleneck during the "coordination and progress monitoring" phase, since the events they have performed through Moodle are related to the "Adapter" pattern and they have written and deleted many lines of code for more than an hour. Furthermore, the spoken communication rates working in lab sessions or remotely are very low; it seems that they are not being coordinated properly.

6 Current progress

So far, the author has been working on the first iteration of the thesis plan. She has carried out a non-systematic review of the state of the art of SSRL and SRL, focusing on the definition of the theoretical models, the adoption of these models in empirical studies and the types of data collected. In addition, a systematic literature review in Smart Learning Environments is being carried out.

Since our main objective is to improve collaboration skills of student groups by detecting patterns of SSRL using data coming from SLEs, the next steps are: i) to identify and describe collaborative scenarios in SLEs that can benefit from SSRL; ii) to identify which data sources can help us detect SSRL patterns; iii) to identify what actionable information we want to generate through SSRL; iv) to explore the use of machine learning techniques (i.e., process mining) to discover SSRL patterns. Then, we have to put them into practice with accessible datasets.

In the following exploratory phase, the author wants to analyze which are the main challenges that students face during collaboration to design early interventions involving teachers. It is expected that the aforementioned interventions can be triggered automatically based on the early predictions.

Finally, the contributions will be evaluated with students and teachers.

The PhD thesis is at an initial step. Further discussion about the proposals, the methodological work and the evaluation strategies could greatly benefit the author for progressing in this dissertation.

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