Emergent Explicit Group Regulation in Small Group Scientific Activities

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In this project we investigate a phenomenon that we name emergent explicit group regulation (EER). In our video data, college freshmen are engaged in small group scientific activities promoting metacognition. Three activities of different types (reading discussion, hands-on model building, and outdoor experimentation) were analyzed qualitatively to identify and characterize EER. We developed a framework of EER to analyze the whole data set of activities, looking for patterns in student group regulation. We found instances of EER involving a context that regulation is "needed", an emergent student regulator, discourse and action of regulation, and effects on learning, such as understanding a topic, making progress on the project, or getting more accurate measurement. Implication for instruction will be generated to better facilitate student metacognition in small group activities.

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I. INTRODUCTION

Working in groups has always been a cornerstone of learning, but as we move towards more modern pedagogical approaches it has become even more important. When students are engaged in a group activity, they often have diverse ideas. Rich ideas can contribute to the group's productivity. Diverse ideas are also challenging to manage. Productive group work requires group members collectively to make thoughtful decisions, take productive actions, and also that they make sure that there is no over concentration of authority.

The effects of students' awareness of their own learning and more broadly of the processes and challenges of learning as a whole, known as metacognition, is of great interest of educational research. Metacognition also informs many aspects of student learning and students' behavior [1–5].

In this paper we investigate how signs of metacognition emerge in small group activities. Specifically, we focus on analyzing the moments that students spontaneously self regulate their learning (rather than incentivized regulation). Group members plan, monitor, and evaluate learning based on their group task and goals [1].

Understanding such phenomena has implications for instruction and curriculum design. In the literature on metacognition we see that metacognition is moving from the hidden curriculum towards an explicit set of goals for instruction [6]. Informed by our research findings, instructor can develop instructional strategies drawing upon student's emergent metacognitive thinking and regulatory skills, enhancing such skills, and leveraging learning.

In this paper, we focus our investigation on the following:

1. How (in what ways) can we characterize the features of group self regulation?
2. How do features manifest in small group discussions, specifically for university freshmen working on science activities during a summer experience focused on metacognitive growth?
3. Within activities, how does emergent explicit regulation affect content learning and learning to collaborate?

II. RESEARCH ON STUDENT METACOGNITION

Our study is situated in the general research area of student metacognition. Metacognition is a broad term, which can refer to one's "knowledge concerning one's own cognitive processes or anything related to them"[2] and "self-regulation–the ability to orchestrate one's learning: to plan, monitor success, and correct errors when appropriate–all necessary for effective intentional learning" [3]. The latter also overlaps with topics such as self-regulated learning (an individual's ability to take control of his or her learning) [4], and self-efficacy (an individual's conceptualization of his or her own competency [5].

Although the definition of metacognition varies, one common theme is students' awareness of their thinking and learning and that they can possibly do something to enhance this learning, which can be manifested in self-regulative behaviors.

In physics education research, different aspects of student metacognition have been investigated by researchers. Sayer and colleagues identified BESM talk–brief, embedded, spontaneous metacognitive talk–that characterizes the moments when students think like a physicist. BESM talk communicates students' in-the-moment enacted expectations about physics as a technical field and a cultural endeavor[7].

Quan and colleagues studied students' self-efficacy and their view of the nature of science. The authors found that gaining more nuanced views about the nature of science coupled to gains in self efficacy [8]. Brown et al. found that giving students explicit incentives to correct mistakes had greater impact on students' performance on final exam [9]. The Kay et al. study shows that most students recognized the value of giving and receiving peer feedback on student-generated multiple choice questions [10]. Stewart et al. found that patterns of regulation were different for higher performing students than for lower performing students[11]. Van De Bogart and his colleagues applied a framework of socially mediated metacognition (SMM) [12] and studied students working in groups solving physics problems. Van De Bogart et al. found that students engaged in SMM at multiple key transitions during the troubleshooting process [13].

Among the above research that studies metacognition, Van De Bogart et al.'s work [13] specifically addresses metacognition in a social context. More research shows that when working in groups, students can take initiatives and engage in productive, collaborative learning, by ways of demonstrating aspects of productive disciplinary engagement (PDE) [14] and deliberately monitoring off-task talks [15]. Milo et al.'s cross context, comparative study on students' PDE in group work reveals a pattern, where high-outcome groups displayed a greater proportion of high-level cognitive activity while working on the task [16]. However, research intersecting metacognition and productivity of student group work is limited.

Our research study elaborates productive student group work through the lens of self-regulation (or more broadly metacognition). We study student emergent, spontaneous self-regulation at a moment by moment level (rather than a course level), this regulation is towards group goals (rather than individual learning goals) in different kinds of activities. This specific topic is important (as discussed in introduction) but has yet been examined in depth (as shown in the literature review). We hope to articulate identifiers and roles of productive self-regulation and to thereby inform instruction.

III. WHAT IS IMPRESS?

The context for the present study is the Integrating Metacognitive Practices and Research to Ensure Student Success (IMPRESS) summer program, which is a two-week program for matriculating Rochester Institute of Technology (RIT) students who are first generation students and/or deaf/hard of hearing students (DHH) [6]. This program is designed to serve as a bridge program for students to learn how to reflect on, evaluate, and change their own thinking through intensive laboratory experiments, reflective practices, and discussion both in small groups (3-4 students) and with the whole class (20 students). The main objectives of the IMPRESS program are to engage students in authentic science practice, to facilitate the development of a supportive community, and to help the students reflect on the science and themselves in order to strengthen their learning habits and lead them to a stronger future in STEM fields.

We are interested in characterizing and exploring the features of student group self regulation during this program. We are aware that the context of our study – a metacognitive educational program – is related to the general topic of our study – student metacognition. The content and pedagogy of the program may play a role in how signs of metacognition manifest in activities. Conclusion drawn from the present study speaks to similar context. Further study is needed to gain a broader view of student group regulation in other educational programs.

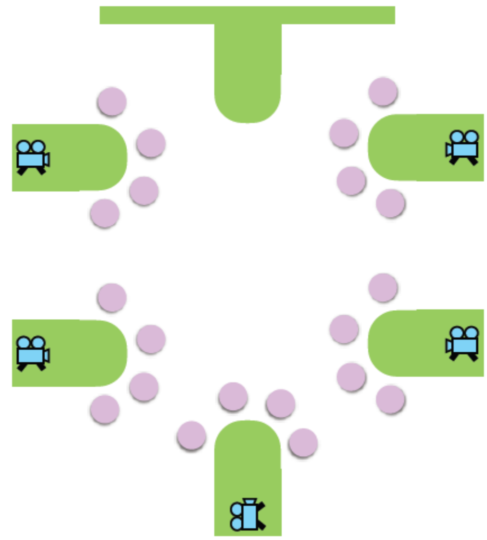

FIG. 1. Layout of the IMPRESS classroom. Students sit at the five tables with cameras, the table on the top of the figure is the instructor table.

IV. METHOD

We conducted a qualitative analysis of IMPRESS video data, identifying typical examples addressing our research questions and generating thick description of the examples [17].

For the duration of the IMPRESS program, each group of students is recorded by a camera when they do small group activities (Figure 1 group activity). When students do outdoor activities, one camera records all groups by circulating between the groups. This method generates a rich set of video files spanning all nine days of the IMPRESS program, broadly split into morning and afternoon subsets for each of the days.

The first three authors of the present work participated in the coding process. We explored the set of IMPRESS videos and identified 29 videos that capture small group activities. The activities are of three types: reading and discussion, indoor experimentation, and outdoor experimentation. We then scanned through the videos and selected good quality videos to start our analysis.

The starting point of our analysis was to identify signs of student metacognition. During the initial analysis we noticed instances of student group self regulation occurring when students collaborate in small group activities. We then examined these instances in detail, characterized the regulation, and developed a framework to describe such phenomena: Emergent Explicit Group Regulation (EER). EER details the discourse, action, positioning, and roles of student group regulation, and can reveal similarities and differences in ways of regulation in different activities. This framework was then refined by being applied to different types of activities – indoor reading and discussion, indoor hands on experimentation, and outdoor experimentation – to compare.

During our analysis of the EER instances, the three authors who participated in coding watched the videos separately and generated ideas and questions about the instances. We then met together and discussed our ideas, to generate common understanding of the instances as well as to come to consensus. When there were aspects on which we did not come to consensus after discussion, we went back and each watched the videos again separately and met again to discuss. We iterated the watching and discussion process until a solid consensus on what we were seeing was achieved.

During this analysis, we were aware that the matter of self regulation of the group and whether it functions efficiently towards the learning goals is a multifaceted issue. Regulation could depend on group dynamics, gender and other similar issues. However, in the present study we are interested in focusing on the ability of each person to position themselves within the group, to recognize moments where intervention is needed, to monitor the procedure and to take initiative.

Also, in the present study we focus on instances where one person is explicitly regulating the group. Of course there could be instances where self regulation of the group is occurring when a person decides not to act. However, the latter case is rather implicit and we cannot determine when this is happening from the data we have on hand.

V. RESULTS

We found that emergent explicit regulation is a common feature of group work. The conditions, context and specific

TABLE I. Comparative summary of EER in three activities.

	Mindset **Reading and discussion**	**Model Construction** **Indoor experimentation**	**Mentos and Soda** **Outdoor experimentation**
Timing	Near the end	Early in the beginning	Middle of the activity
Who	Herb	Allie	Unclear
Action	Arms out separating two students	Grabs the tank and puts in paddles	One student is holding two meter sticks. Another student is holding tape. Together they tape a second stick on top of the first one.
Discourse	“Ahhh.. wait, wait. Fixed mindset is .... (to one student) Fixed mindset is.... (to the other student)”	“Here. Better idea. Better idea.” Other student: “Say it before you...” “No. I am gonna do it, and then you guys...”	White Shirt: “this is one hundred, and this is...”. Black Shirt: “yeah. but... won’t it be easier to connect them this way?”
Positioning	Herb moves to the middle.	Other student moves to the side.	group members circle around equipment.
Effects	Summarizing understanding. Address both arguing students. Trying to stop arguing to win. Directing to understanding ideas.	Building a model. Dismiss other ideas Stopping possible collaborative discussion.	Getting a more accurate measurement. Take initiatives and make adaptation to the original instruction in order to get better data. The two students who are trying to connect the sticks are collaborating and trying to figure out a best way.
Evaluation	Shifting toward being productive	Partially productive	Highly productive

characteristics of each instance of EER vary and relate to the effect on the group’s productivity. Not all EER is equally productive.

EER features that can be demonstrated in activities include: timing of demonstrated EER, the person who takes the initiative and regulates the group, regulative discourse, actions taken to regulate, physical positioning change when EER emerges, context in which an emergent EER would be helpful or necessary, and the direction the EER leads to.

The above features can be directly observed in the data or inferred. When a feature is inferred, a strong consensus of all of the authors that this indeed should have taken place was required. Only if all authors where confident, based on observed indicators present in the data, that this feature must indeed have taken place outside of the camera’s view was such an inferred feature retained for use. Further this was done only if the critical moment of group regulation was directly observed.

Below we provide detailed descriptions of three examples of EER, with further information found in Table I.

A. Mindset–Reading and Discussion

In the Mindset reading and discussion activity, four students discussed articles on growth and fixed mindsets [18]. EER was observed near the end of the activity when two members of the group are arguing intensively and in a way that makes it clear that conflict is about to occur. One student says a fixed mindset is bad because it limits one’s ability to learn. The other students insists that a fixed mindset sometimes can be good because it can help one to know and accept the limit and move on. The two students have been arguing on the same point for the majority of the time assigned to discussion, and time approaches the end. At that moment a third student, Herb, positions himself between the two arguing students and attempts to resolve the tension.

The regulation occurs on the level of behaviour. In the middle of the discussion, Herb has moved to sit between the two students and listened to the argumentation. When EER occurs, Herb reaches his arms out, physically separates the two students, calls a stop by saying "Ahh... Wait. Wait." and then, one after the other, summarizes each student’s idea by rephrasing and facing to the student. While Herb is finishing his words, the instructor calls the whole group to gather together and to the following whole-group activity.

With his discourse, action, positioning and behavior, Herb is acting to regulate the behaviour of their fellow group members. The intention seems to stop arguing and direct to understanding. In that sense, regulation is emerging out of a set of beliefs which defines what is an acceptable and productive way to argue one's point of view, and what is a meaningful goal to argue. We would categorize this EER as "shifting toward being productive."

B. Model Construction–Indoor Experimentation

In the Model Construction, an indoor experimentation activity, groups of four students are constructing a 3-D model that simulates the green house effect. To do so, students used provided materials to simulate natural objects: a plastic tank filled with water (ocean), plastic wrap (layer of green house gas), aluminum foil (high-reflective rate surface of oceans), paddles (solid ground), and a table lamp (to simulate the sun as heat source). EER was observed early in the beginning of the activity when the group is mostly chit-chatting and does not seem to have a clear direction. A student, Allie, takes initiative, grabs the tank and starts to add paddles to the bottom of the tank while the others will watch her actualising her idea.

When Allie grabs the tank and puts the paddles in, she says: "Here. Better idea. Better idea." when she starts building. A student on her side asks Allie to explain her idea:"Say it before you..." However, Allie refuses to explain and continues building: "No. I am going to do it. You guys are going to see." Another student then moves to the side of the table, which makes Allie in a center position of the group (before this moment, Allie was on the side).

This EER has mixed effects. On one hand, it leads the group to build an initial model, moving toward their goal. On the other hand, this moment could be seen as a case of over concentration of authority where other students were denied agency by the one member. In this instance the group ideas are not equally expressed and heard and therefore the group becomes less collaborative. We would categorize this EER as "partially productive."

C. Mentos and Soda–Outdoor Experimentation

In the Mentos and Soda, an outdoor experimentation activity, we observe a group of three students do a "Mentos and Diet Coke" experiment to examine the solubility of CO_2 in water as a function of the temperature of the liquid.

In this experiment students drop three pieces of Mentos candy into a bottle of diet coke, the presence of the Mentos triggers the violent release of the undissolved CO_2. Students were given a meter stick so that they can measure the height of the resulting plume of expelled gas as a means of indirectly measuring the amount of undissolved CO_2 present in the bottle at a given temperature.

There are four small groups shown in the video we observed, but as this is an outdoor activity there was only one camera and the camera did not split its time equally between these groups. The camera captured some interesting interactions in groups 2 and 3.

From what is shown in the video, we saw that group 2 (four students) uses two meter sticks taped together (head to end) and therefore uses a longer stick when measuring the height of the plume. All others groups use only one meter stick. We also noticed that before group 2 drops the Mentos in the Coke, group 3, who has used one meter stick, had done the experiment and their plume rose higher than the top of one meter stick. While group 3's first trial is shown on the video, group 2 is not shown in the video.

Based on what we saw in the video, we infer that Group 2's subsequent actions (taping two sticks together) are likely to have resulted from observing group 3's trial (plume height higher than one meter). It is shown in the video that the physical distance between the two groups is close enough for them to easily see each other.

In the video, one student in group 2 reads their self-made, extended ruler and reads: "This is one hundred, and this is ..." Another student adds: "Yeah. but... wouldn't it be easier to connect them this way?" They then collectively hold the sticks and the Soda bottle and drop Mentos. It is shown in the video that their gas plume is indeed a little bit higher than one meter.

In this activity we observe that the group functioned in a more "metacognitive" way. They regulated their actions by observing others, evaluating their attempts and redirecting their own actions. We would categorize this EER as "highly productive".

VI. DISCUSSIONS AND FUTURE WORK

The examples demonstrate similarities in how EER is instantiated in different types of activities. There is a need to take an initiatives and act, the regulating person often becomes in the center of physical positioning, regulative discourse and action often occur simultaneously, and regulation has effects on content learning and social learning (collaboration). EER appears to be a promising framework to help researchers understand student emergent metacognition in group work.

The EER framework can help instructors be more attentive to emergent regulations and use the opportunity to guide students towards more productive regulation, and become reflective about their group regulation; thus to foster student explicit metacognition and enhance learning.

Our results are preliminary. Future work is needed to analyze more videos, refine the framework, and examine quantitative patterns of EER in a bigger data set.

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