Self-regulation and Collaboration in a Discovery Learning Environment

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Abstract

This study examined how students regulate their learning within an online collaborative learning environment designed to promote inquiry learning. Regulation of inquiry learning, as defined by Njoo & De Jong (1993) includes two basic processes, planning and monitoring. Unraveling self-regulation of students within such learning environments is further exacerbated by collaboration. Designing self-regulatory support within learning environments requires an understanding of how students work together within the environment. In this study we sought to identify and describe how students (N=21) collaboratively planned and monitored within an initial (2 hour) session with an online collaborative discovery learning environment called CoLab. Ultimately the goal of this study was to provide recommendations for the design of CoLab and its tools in order to optimize support for self-regulation in areas where students need it.

1. Introduction

Formative evaluation is a goal directed process which occurs often throughout the design of instructional media and materials. According to Weston, McAlpine, & Bordonaro (1995) formative evaluation should serve the goals of the instruction which includes such concepts as effectiveness, efficiency and appeal. According to their model of formative evaluation different questions can be asked depending on the goal being addressed. If the goal of formative evaluation is effectiveness, questions are asked regarding whether students are achieving what it intended, and if the goal of the formative evaluation is efficiency, the questions asked might include whether the instruction works the way it was intended to work in the actual setting. Thus far two prior formative evaluation studies have been conducted to evaluate the usability of Co-Lab with the focus being more on the efficiency and appeal of the environment. However these studies although yielding fruitful results for environment design pertaining to it’s user-friendliness regarding tools and levels of intuitiveness, did not examine the use of Co-Lab the way it is intended to be used, i.e. to conduct a scientific inquiry. Additionally these studies did not address any issues regarding whether students were achieving what was intended with regards to regulation of their inquiry.

This study seeks to expand upon these prior works in order to examine efficiency in terms of how students work with Co-Lab with minimal guidance from evaluators or the environment. Thus the purpose of this study is three-fold. 1) Describe working patterns and group approaches to the learning task. 2) Obtain base-line data which shows how students are or are not regulating their inquiry and 3) Identify problems which students have in both the use of Co-Lab and it’s tools and in regulating their inquiry. Ultimately the goal of this study is to provide recommendations for the design of Co-Lab and it’s tool in order to optimize support in areas where students need it.

One area which consistently is a problem for students both within computer environments and learning in general is regulation of their own learning. Regulation of inquiry learning, as defined by Njoo & De Jong (1993) includes two basic processes, planning and monitoring. In this study, we sought to identify and describe the students and group’s learning activities during the initial stages of a Co-Lab session.
2. Method

2.1 PARTICIPANTS
39 students from higher-secondary education, aged 15 to 17 were used for this study. The students were in a nature and technology track and have an emphasis in their curricula for courses in science and technology. The participants worked in groups of 3, which resulted in 13 triads which were assigned by the experimenter.

2.2 MATERIALS
Co-Lab (version April 2003) was installed on a local server and was accessed through a local area network. Table 1 shows the tools that were operational for each room to the students within the system. A more detailed explanation of the Co-Lab environment can be found in the D5 document.

Table 1: Overview of operational tools and their location

<table>
<thead>
<tr>
<th>Meeting room</th>
<th>Lab room</th>
<th>Theory room</th>
<th>Hall</th>
<th>Generic tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Coordinator</td>
<td>Simulation interface</td>
<td>Model editor</td>
<td>Help tool (mission statement)</td>
<td>Navigator</td>
</tr>
<tr>
<td>Help tool</td>
<td>Table</td>
<td>Table</td>
<td>Chat (+sentence openers, free-threaded)</td>
<td>Control tool</td>
</tr>
<tr>
<td>Graph</td>
<td>Graph</td>
<td>Help tool</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help tool</td>
<td>Help tool</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Both the greenhouse effect building and the water management buildings were used in this experiment. The greenhouse effect building was used for the introduction to Co-Lab and the introduction to modeling. The water management base module was used during the experiment. The goals of these modules are explained briefly in the procedure sections below. Given that the purpose of this study was to identify the basic working patterns of initial work with Co-Lab and to examine their initial planning and monitoring activities the task given to students was shortened and simplified.

2.3 ENVIRONMENT SETUP
In addition to the tools specified above, Co-Lab was setup with materials for the students to use during the experiment. The greenhouse gas building was setup with a preset model for the students to explore and use during both the introduction to Co-Lab and the modeling introduction. A mission statement for both the greenhouse gas building and the water management building are also specified. These are explained in more detail in the procedure section. Finally, the Process Coordinator tool was setup with a list of top level goals. These goals are found in Table 2 below.

Table 2: Process Coordinator goals
- Before You Begin
- Modeling and Hypothesis Generation
- Data Collection
- Drawing Conclusions
- Evaluation

The purpose of the Process Coordinator is to provide students with a tool to plan and monitor their work in Co-Lab. In order to see how students plan and monitor their inquiries only top level goals were provided to the students.

2.4 PROCEDURE

Introduction to Co-Lab
At the beginning of the experiment students were divided into the triads that they would be working in for the remainder of the session. Observers guided single triads through an introduction to Co-Lab at the beginning of the session. This introduction took about 40 minutes. The observers were seated with the groups around one computer. The observation checklist designed for the first usability
studies was used to walk the students through the Co-Lab System\textsuperscript{1}. The observers directed students to take certain actions in order to learn how to use the environment. The introduction covered the basics of login procedures, the Co-Lab building metaphor, environment navigation, and all tasks related to tool use. After the introduction students were directed to work individually on an introduction to modeling.

**Modeling Introduction**

Designing systems dynamic models was not a familiar activity to these students, and is in fact a high level skill which most high school students are not familiar with. In order to control for the difficulties students might have with modeling which might interfere with a true assessment of the overall use of Co-Lab in a natural setting, it was deemed necessary to provide this introduction. The modeling introduction had students work individually through reading materials which explained systems dynamic modeling language and symbols as well as the use of the model editor in Co-Lab. In the modeling introduction students were introduced to the various variables types (constant, auxiliary, flow and stock) and their meanings, as well as the basic functions of the model editor. Students were given a simplified model to work with for this introduction. The modeling introduction utilized the base module of the green house gas building. The simplified model is shown in Figure 1.

![Diagram](attachment:figure1.png)

**Figure 1: Simplified Model for Modeling Introduction**

**Experimental task**

After the modeling introduction was completed, students took a short break. Upon returning to the experimental setting students were given login information for the water management building in order to begin their task. The experimental task was a modified version of the base water module in Co-Lab. This task was given to the students in the mission statement provided in the environment setup. The mission statement gives a very brief introduction to water management which contextualized the domain within recent flooding incidents in the Netherlands. They were then told that in order to understand the basics of water management they could think of a container which catches rain from a drain pipe. This container has a tap at the bottom to drain the water out of the container and is housed under a water grate where water flows into the container. This metaphor introduces them to the water tank simulation found in the base water module of Co-Lab, where water flows in from a tap and out through a hole. By varying the variables of tank diameter, diameter of the hole and the flow from the tap students can see the effects of these various factors on the contents of the water tank. The task presented to the students was to work with the simulator until equilibrium between the inflow and outflow of the tank was reached and then to construct a model of this phenomena using the model editor. Students were pointed to the Process Coordinator tool as a first step in planning their inquiry. Figure 2 shows a picture of the water tank simulation the students used.

\hspace{1cm} \textsuperscript{1} See Usability Study 1 Report WP4
2.5 MEASURES

Log file analysis
Logfiles of student actions during Co-Lab use were used as the primary data source for student actions and tool use within Co-Lab. A sample of a logfile is shown in Table 3. Prior to the data analysis, these logfiles were examined and a coding framework was established which showed which logfile codes matched which student actions. A filtering program was created which allowed the raw logs to be brought into Excel for analysis. Refined filters to search the logs for specific combinations of actions were also created.

Table 3: Sample log file

<table>
<thead>
<tr>
<th>flr</th>
<th>grp</th>
<th>bid</th>
<th>rm</th>
<th>date</th>
<th>user</th>
<th>name</th>
<th>sender</th>
<th>type</th>
<th>typeVT</th>
<th>variable</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>-1</td>
<td>11:24:04</td>
<td>Mark</td>
<td>changeLocation</td>
<td>broker</td>
<td>internal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>11:24:04</td>
<td>Mark</td>
<td>changeLocation</td>
<td>broker</td>
<td>internal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>11:24:07</td>
<td>Bob</td>
<td>chatmessage</td>
<td>ChatTree</td>
<td>application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>11:24:16</td>
<td>Anne</td>
<td>chatmessage</td>
<td>ChatTree</td>
<td>application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>11:24:21</td>
<td>Bob</td>
<td>chatmessage</td>
<td>ChatTree</td>
<td>application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>11:24:25</td>
<td>Anne</td>
<td>setValue</td>
<td>environment</td>
<td>internal</td>
<td>Flow_from_tap</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>11:24:25</td>
<td>Anne</td>
<td>VisualToolEvent</td>
<td>JvTankLab</td>
<td>application</td>
<td>ChangeEvent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>11:24:26</td>
<td>Anne</td>
<td>setValue</td>
<td>environment</td>
<td>internal</td>
<td>Flow_from_tap</td>
<td>97.0</td>
<td></td>
</tr>
</tbody>
</table>

This log sample shows group four actions on floor one of building one. It also shows the date and time of the action, and the user login, or the student performing the action. The name, Sender, Type, TypeVT, and fields denote the type of action and what tool was used for the action. Included in this sample is the variable and value fields which show that Anne changed the Flow from the tap variable from 100.00 to 97.0 ml/sec. Note that Table 3 does not show all the fields which are included in a full log.

Navigation within Co-Lab
For this study particular attention was paid to the room use patterns of the students. Specific patterns of room changes were constructed using the “Name”, “Room”, and “Date” fields as indicators in the logs. In addition, durations of room changes were also calculated. Durations of room changes were calculated from and to the moment of a room change. The moment of a room change is logged in Co-Lab under the room field as a -1, in combination with the “name” field specifying “changeloglocation”. This can be seen in the first two lines of Table 3.

Specific tool use was also examined when it was deemed fruitful for the analysis and purposes of this study. The Process Coordinator use and actions were examined, for example only if there was significant durations of stay in the meeting room, where the Process Coordinator is housed.
Chat files
Coding of the chat files followed a stepwise bottom-up approach. First the basic unit of analysis was determined by segmenting chat files into utterances. An utterance was defined as a collection of words with a single communicative function. Utterances are separated by a “perceptible pause” which in case of synchronous online communication often comes down to sending the message. Each utterance was then classified according to its function in the dialogue. Here a distinction was made between cognitive, regulative, affective, procedural, and off-task utterances (see Appendix A).

Next, conceptually related utterances were merged into episodes. Consistent with Van Boxtel (2000), an episode was operationally defined as a set of expressions that is meaningful at the content level. As this study sought to identify which regulatory processes students spontaneously adopt, only the regulatory utterances were grouped into episodes with a distinction between regulation of the collaboration and regulation of the learning task as the two main categories.

2.6 Delimitations
Throughout the course of this experiment technical difficulties with the Co-Lab environment prevented groups from using Co-Lab to its fullest potential. Of the thirteen groups which participated only seven groups were able to use Co-Lab for between an hour to two hours. Thus the results of this study are not generalizable and true comparisons between groups other than descriptively aren’t possible. Thus, the data analysis described in the next section takes a descriptive and explorative approach using the seven groups who were able to work with Co-Lab for a duration of between forty-five minutes to an hour and a half. Additionally the Process Coordinator tool was not functional beyond opening and closing (for some groups) and not at all for others during the experimental task. In view of this fact, the opportunity to examine students unsupported and spontaneous regulatory behavior was presented and utilized during the data analysis. This approach allows for deriving guidelines for the design of regulation support which are described in the discussion section.

3. Results
As described in the previous section an explorative and descriptive approach to the data analysis is taken. As a starting point a description of how the groups moved through the environment is described and basic navigational issues are described. Following this section, an analysis of how the groups worked collaboratively is presented with a description of two different approaches to the learning task shown from the analysis. Finally an analysis of the students regulatory behavior is described.

3.1 Basic navigational issues
Room visits
In Co-Lab, students have to move across rooms to perform learning activities. Figure 3 shows the average frequency of room visits. Judging by these scores, the Lab room was the most popular place to be. In contrast, the Meeting room was visited the least. On average, the groups went to this room less than two times.
Figure 3: Mean number of visits per room

This pattern was maintained when looking at the relative length of stay in Figure 4. On average, the groups spent 83 percent of their time in the Lab and Theory room. The length of stay in the Hall was approximately 16%, leaving a mere 1% of time for the Meeting room.

Figure 4: Mean proportion of time per room

Table 4 shows how navigation and room visits differed across groups. Considerable deviations were observed in the Hall. Group 2 went there 21 times and spent over one third of their time in that room. Re-visiting the Hall after the initial login might indicate students re-grouping, or checking the mission statement for information. The latter claim was not supported by Group 2’s the chat logs and Help tool use. Although they opened the Help tool every time they entered the Hall, their chat did not contain evidence of extensive discussions, or fact finding activities. Groups 3 and 10 in contrast to Group 2 had the lowest amount of time spent in the Hall. An examination of their help tool use in conjunction with the chat shows that in their initial visit they spent time discussing the mission statement and subsequent chat logs reveals that both groups understood the mission statement sufficiently to continue with the activity without going back for information or to check understanding.

Table 4: Number of room visits and length of stay per group

<table>
<thead>
<tr>
<th></th>
<th>Number of visits</th>
<th></th>
<th>Relative length of stay (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hall</td>
<td>Lab</td>
<td>Theory</td>
<td>Meeting</td>
</tr>
<tr>
<td>Group 1</td>
<td>8</td>
<td>11</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Group 2</td>
<td>21</td>
<td>19</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Group 3</td>
<td>5</td>
<td>13</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Group 4</td>
<td>6</td>
<td>16</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Group 5</td>
<td>9</td>
<td>11</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Group 6</td>
<td>8</td>
<td>22</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Group 7</td>
<td>7</td>
<td>11</td>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>

Note. For reasons to be explained below, scores indicating room visits are calculated by adding the scores of individual group members. Time is the ratio of the mean time spent in a room for all group members to the total time spent in the environment.
Deviations from the general group pattern were also observed in the Theory room. Group 1 had a low frequency count for Theory room visitation, but spent 42.4% of their total time there. Together these findings imply that this group rarely left the room and concentrated on modeling for a long time. Groups 2 and 6 spent the least amount of time in the Theory room—yet for different reasons. Group 6 was unable to attain equilibrium in the water tank simulation despite often detailed and diligent work in the Lab. Thus they felt no real reason to visit the Theory room because they had nothing to model. Group 2 did attain equilibrium in the tank, but somehow missed out on the second part of the assignment, namely to model the tank. Their incomplete understanding of the task may have been due to the fact that this group was by far the least focused on the learning task of all the groups having the highest percentage of off-task communication (see next section for further discussion). This could also explain why these students showed a relatively high number of visits to the Theory room: they purposelessly wandered around.

The Meeting room had the lowest number of visits of all the rooms. Two groups stand out from this, namely Group 1 and Group 10. Group 1 did not visit the Meeting room at all. Their chat logs suggest that they preferred to “get busy” rather than come up with a plan. After reading the mission statement there is one instance where a student asks where the Process Coordinator tool is, but this comment seems to be “lost” in the chat as it was not responded to by the other students (see Excerpt 1). Instead the students seem to plan directly from the mission statement by drawing the conclusion that they need to adjust the parameters of the simulation first and all decide to go to the Lab room. This may indicate that the students did not see any immediate need to plan using the Process Coordinator or visit the Meeting room. Group 10 had the highest number of visits and the highest percentage of time spent in the Meeting room. This group was the only group which showed attempts at planning using the Process Coordinator and showed a higher instance of discussing their overall approach to the learning task.

Excerpt 1

1. Frank where is the Process Coordinator again?
2. Odette hang on I’ll ask
3. Romy right, you do that
4. Frank so we should enter the correct parameters in the simulation variables
5. Frank ...
6. Frank well..?
7. Odette all right
8. Romy ummm yeah...you stay in control then
9. Odette are we going to the lab now??
10. Frank we are going to the lab

Room changes

Figure 5: Room change patterns
In addition to information concerning the students’ stay in rooms, it is also interesting to examine how they move across rooms. As can be seen from Figure 5, almost 80% of the room changes took place between the Hall, Lab, and Theory room. The Meeting room was a relatively isolated place, as it was involved in 22% of the room changes. This means that students went to the Meeting room on 11% of the occasions. This tentative conclusion was substantiated by the mean number of moves to the Meeting room per individual student (see Figure 6)

![Diagram showing room changes](image)

**Figure 6: Mean number of moves to the Meeting room per individual student**

Figure 7 gives a more detailed overview of the room changes. Being a sequential representation, it also illustrates how the groups organized their learning process. Two impressions can be drawn from these bar charts. The first concerns the groups’ working pattern, that is whether the groups worked together (collaborative) or apart (cooperative). The second is an overall impression of how groups approached the learning task while working with Co-Lab.

**Collaborative working patterns and deviations**

A visual inspection of the bar charts in Figure 7 reveals that in general the groups’ working pattern was fairly collaborative. However, Groups 2, 4 and 8 show evidence of deviations from working collaboratively. Their chat files were examined to check whether or not students made a conscious decision to work in separate rooms.

Group 2 showed a tendency to work apart during the later stages of their time with Co-Lab. As their chat files contained only one instance of assigning tasks which explains room changing, it is probably correct to conclude that this group did not work collaboratively during the latter part of their session.

Groups 8 showed a similar deviation from collaborative work patterns at the end of their session after they have moved to Floor 2 due to technical difficulties. Following a collaborative move from the Lab to the Theory room, the second student takes control and begins modeling. Student 1 and 3 stay a bit, then agree to return to the Lab to make graph and announce their decision. The second student continues modeling for approximately ten minutes before joining the others in the Lab room. She then returns to the Theory room and actually goes to the Meeting room, (not shown in Figure 7 due to short duration), but there is no announcement or agreement with the other students regarding these room changes. Student three follows her in, leaving student 1 behind in the Lab room. Again no explicit agreement or statement is made about this.

The first group member in Group 4 tended to deviate from the collaborative pattern throughout almost the entire session. Most deviations occurred between Lab and Theory room, and the chat revealed very few instances of agreed upon room changes. In fact only two instances seem to be derived from stated actions which imply room changes.

**Approach to the learning task**

The room change patterns from Figure 7 also provide insight into the different approaches groups took with the learning task. In looking at the bar charts two approaches to the learning task are found with
some deviation from the patterns. Groups that took an explorative approach to the task and groups which took a sequential approach to the learning task.

*Explorative groups*

The majority of groups can be classified as exploratory. These groups, 1, 4, 8, and 10 approached the learning environment and the task with initial work in the lab, moving to the theory room briefly, then back to the lab before finishing their sessions with significant time modeling. Before moving to their initial visit to the theory room to begin modeling, the logs indicate that these groups achieved equilibrium in the simulation water tank. The structure of the lab work these groups engaged in doesn’t reveal any systematic experimentation based on formal hypothesis making. Rather the groups favored an explorative approach of running the simulation to see the effect of variables and then “intuiting” from this which variables they needed to change. Further simulation runs show a “hit or miss” approach in just trying to change inflow and hole diameter until equilibrium was attained.

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\(^2\) Group 4 does not actually achieve equilibrium in the lab, although the animation may have showed this. A recreation of their experiment reveals that if the water tank simulator were allowed to run for a longer time, it would eventually run out using the settings group 4 used for hole diameter and the flow from the tap. However the settings are so minimal the animation shows an equilibrium when in fact there isn’t any. This is a nice example of how students have difficulties drawing accurate conclusions from visual cues as described (Land, 2000).
Figure 7: Room pattern by group
In their initial theory room visits prior to returning to the lab, these groups tended to explore the model editor. These all tried to understand the model editor in this first visit. They then returned to the Lab to gather more information such as variable names, and types (i.e. stocks, auxiliaries, etc.) and settings before continuing with modeling. A good example of this is found in Excerpt 2 below. This shows a chat excerpt from Group 4. Fred is in the Lab looking at settings in the table in order to identify variables to use in the model. His reference at the end of making a theory, is in reference to modeling in the theory room.

**Excerpt 2**

1. Fred I have to copy the variables.
2. Fred I am copying the variables
3. Fred Do you see the table now?
4. Fred That is level in the tank
5. Fred thus the capacity
6. Fred See it almost always stays the same.
7. Fred Is it possible for us to consider that a constant?
8. Fred I have found two other settings
9. Fred So now we go to make a theory.

In their final phase of modeling, all of these groups had model fragments in various states in the model editor and most made an attempt at running their models. By model fragments it is meant that students used all the types of variables (stock, flow, auxiliary, and constant) and had drawn relationships between them. With the notable exception of group 4, all groups specified names of variables and attempted some variable settings. Group 4 only attempted to label one variable in their model. Additionally only one group, group 10, attempted to specify formulas for their model variables. Given the lack of any real formula specifications for their model, none of the groups would have been able to get beyond a basic model sketch and perform any higher order modeling activities such as testing and revising their models.

**Sequential groups**

The remaining groups, group 2, 3, and 6, took more of a sequential approach to the learning task, starting first with lab work uninterrupted by theory room visits or modeling activities long enough to have done anything useful. The structure of the lab work for these groups is similar to those of the explorative groups. Their logs do not reveal any systematic method of experimentation nor do they discuss specific formal hypothesis in the chat. Rather they engage instead in exploring the variables and “intuiting” hypothesis and variables settings in order to achieve tank equilibrium. An example of this is found in Excerpt 3, Group 2’s chat log.

**Excerpt 3**

1. Judith You have to copy the variables.
2. Lonneke Yes that’s correct
3. Frank Almost
4. Judith So you have to simply make the flows the same size or not?
5. Lonneke I don’t understand this
6. Lonneke Flow from the tap, that’s what you should change

These groups end their sessions (with the exception of group 6) with modeling activities in the theory room which is not interrupted with short periods in the lab. As explained previously group 6 did not achieve equilibrium in the lab which may explain why they did not proceed to the modeling phase of their Co-Lab session. Groups 2 and 3 did achieve equilibrium in the lab according to an analysis of their chat records before proceeding to the theory room to model. However, Group 2’s log shows no evidence of any modeling activities in their log records, nor do they refer to any in their chat log. The chat fragment used in The chat log for their time in the theory room reveals mostly off task communication and some regulatory activities mostly consisting of “What should we do?”. Group 3’s logs show evidence that they did attempt some modeling however only minimally so. They did not specify any variables and attempt to specify one formula. All other variables were left unspecified and without any names. They did not attempt any runs of their model before their session was over.
3.2 Regulation

According to Co-Lab’s design philosophy, a substantial part of the regulation should take place in the Meeting room using the Process Coordinator (PC) tool. Students use this tool to create an overall plan by stating goals and subgoals, and to monitor progress towards this goal. Instances of regulatory behavior can also be observed in the chat discussions. Students may discuss their planning, comment on progress, or express their understanding of the content.

As the visits to the Meeting room were infrequent, scanning the logfiles for use of the PC may reveal only a fraction of the groups’ actual regulatory behavior. Furthermore, as students spent less than 1% of their time in the Meeting room, it seems unlikely that they performed meaningful planning and monitoring activities. Data for PC use bore this out (see Table 5). Of the six groups that visited the Meeting room, groups 3, 6 and 8 inspected the PC. That is, they only attempted to open and close the PC, but did not try to go beyond opening and closing. This may have been because the PC when opened did not appear correctly, and thus the groups could not access any of its features. Groups 2 and 4 also explored features in the PC such as the history, links, hint or report tabs, but they did not attempt to make any changes to it’s content such as adding goals or notes. Group 10 was the only group that tried to actually use the PC as planning tool. They attempted to change variables within the PC, such as adding a goal, subgoal or note. This group attempted to make these changes a total of 14 times, according to their log records. Their attempts were unsuccessful however, and their chat discussions indicated that this was probably due to technical imperfections. Together, these findings indicate that regulatory data has to be scored entirely from the chat discussions.

Table 5: Use of the Process Coordinator tool (PC)

<table>
<thead>
<tr>
<th>Group</th>
<th>Non-Use</th>
<th>Inspect</th>
<th>Explore</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC use</td>
<td>1</td>
<td>3.6,8</td>
<td>2.4</td>
<td>10</td>
</tr>
<tr>
<td>Frequency (min.)</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Frequency (max.)</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Time (min.) ¹</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>Time (max.)</td>
<td>0</td>
<td>2</td>
<td>146</td>
<td>166</td>
</tr>
</tbody>
</table>

¹ Time in seconds.

Descriptive chat data

In all, the groups wrote 2574 chat messages containing 2605 utterances. As shown in Table 6, approximately 25% of the utterances were off task. Although online groups often begin their sessions social talking –for instance to introduce each other or to wait until all group members are present–, this was no the case here. Most groups were anxious to start the learning task, and some did not even have the courtesy to wait for all group members to login. Group 10 was an exception: two girls were social talking while waiting for the third group member who had difficulties logging in to the environment (see Figure 7).

Table 6: Classification of utterances

<table>
<thead>
<tr>
<th></th>
<th>Cognitive</th>
<th>Regulatory</th>
<th>Affective</th>
<th>Procedural</th>
<th>Off task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>11.07%</td>
<td>32.55%</td>
<td>3.36%</td>
<td>18.12%</td>
<td>34.90%</td>
</tr>
<tr>
<td>Group 2</td>
<td>9.81%</td>
<td>36.11%</td>
<td>1.85%</td>
<td>10.37%</td>
<td>41.85%</td>
</tr>
<tr>
<td>Group 3</td>
<td>11.46%</td>
<td>40.83%</td>
<td>8.54%</td>
<td>15.00%</td>
<td>24.17%</td>
</tr>
<tr>
<td>Group 4</td>
<td>25.71%</td>
<td>44.00%</td>
<td>5.14%</td>
<td>13.71%</td>
<td>11.43%</td>
</tr>
<tr>
<td>Group 5</td>
<td>17.54%</td>
<td>44.03%</td>
<td>5.97%</td>
<td>10.07%</td>
<td>22.39%</td>
</tr>
<tr>
<td>Group 6</td>
<td>13.93%</td>
<td>38.31%</td>
<td>4.73%</td>
<td>30.60%</td>
<td>12.44%</td>
</tr>
<tr>
<td>Group 8</td>
<td>13.93%</td>
<td>38.31%</td>
<td>4.73%</td>
<td>30.60%</td>
<td>12.44%</td>
</tr>
<tr>
<td>Group 10</td>
<td>21.49%</td>
<td>33.03%</td>
<td>6.33%</td>
<td>18.55%</td>
<td>20.59%</td>
</tr>
<tr>
<td>Average</td>
<td>15.86%</td>
<td>38.41%</td>
<td>5.13%</td>
<td>16.63%</td>
<td>23.97%</td>
</tr>
</tbody>
</table>
Groups 1 and 2 had the highest proportions of off-task utterances. Off-task discussions increased toward the end of the session. In Group 1 for instance, one student kept working on the learning task, and occasionally reported back to his group mates, who were engaged in off-task communication. In Group 2, off-task communication was relatively high throughout the entire session, but here the intensity increased towards the session end as well.

Another striking result is the consistently high proportion of regulatory utterances, ranging from 32 to 44%. To get a better understanding of the content of the regulatory talk, regulatory utterances were grouped into episodes. An episode conveys a single idea and is operationally defined as a set of utterances that are meaningful at the content level. As this study aims to identify which regulatory processes students spontaneously adopt, only the regulatory utterances were considered in the analyses. Regulatory episodes were divided into two broad categories: collaboration and learning task, containing 133 and 47 episodes respectively.

![Figure 8: Occurrence rates of episodes for categories indicating regulation of the collaboration](image)

**Regulation of the collaboration**

Regulation of the collaboration serves to establish and maintain a common focus. Figure 8 presents an overview of the episodes of the regulation of the collaboration. An important aspect of regulation in synchronous online collaboration is to know the whereabouts of the other group members. Toward this end, six groups exchanged greetings when first logging in to the environment. These messages were typically brief, mostly a simple “hello” or “hi there”. Similar expressions were used to signal one’s presence after room changes, but these greetings occurred somewhat inconsistent: a group who greeted on one room change, did not necessarily do so on the next change. Greeting also included episodes in which students announced signing off. These greetings were observed in only one group, which may be due to the conditions under which the experiment was conducted (the experimenters announced when a session was over).

Discussing room changes is another instance of regulation of the collaboration. **Excerpt 4** nicely illustrates a collaborative decision to visit the Meeting room. It also shows a typical greeting episode in lines 6-8.

**Excerpt 4**

1. Jane should we go to meeting, theory or lab
2. Mary let’s meet :D
3. Odette hahahaha YEAH(H)
4. Mary because that’s where the goals are, right?
5. **The group moves to the Meeting room**
6. Mary welcome to my meeting room
7. Jane haha
8. Odette hello

Not every room change was elaborated on, however. Group 4, for instance, moved across rooms quite often (see Table 4), but their chat files contained no room change episodes. In general, about 35% of the room changes was discussed in a regulatory episode. The remaining 65% comprised instances of one student merely announcing that he or she went to a different room, without making this decision
subject of discussion. On other occasions, a student simply headed off to a different room without notice; his group members could tell his new location from the control tool, as illustrated in Excerpt 5.

Excerpt 5
1  Carl  Rob, why are you somewhere else?
2  Carl  come to the lab
3  Jack  what’s Rob doing?
4  Jack  what’s he doing there!
5  Jack  in the theory
6  Rob  yeah yeah I’m in
7  Carl  OK then stay in
8  Carl  so we can help Jack

Such wanderings further illustrate a lack of agreement on task division. Despite the fact that most groups worked quite collaboratively, students occasionally agreed on a division of tasks, as is shown in Excerpt 6.

Excerpt 6
1  Frank  Yes, I is in control
2  Frank  You should think along
3  Frank  and type it in here
4  Odette  gosh...duh...
5  Frank  and I will enter it all
6  Romy  okay

On some occasions, task divisions implied a room change. In Excerpt 7, the group has just moved to the Theory room to start modeling, but one student (Joice) reminds that they have not yet saved their graph in the Lab.

Excerpt 7
1  Marco  What are you doing?
2  Bart  trying to make a model
3  Bart  but I don’t understand much of it
4  Joice  shouldn’t we save that thing first
5  Bart  yeah, do it
6  Bart  have you saved it Joice?
7  Joicec  no I couldn’t
8  Bart  I’ll try

Joice goes to the Lab to save their graph. Marco and Bart discuss the experiments until Joice returns

Control changes were another topic of conversation. Although the control tool allows students to request control by clicking the corresponding button, control changes were frequently discussed before they were put into practice. During the initial phases this may have been due to the fact that the technical operation of control change feature was unclear (see for instance line 3 in Excerpt 8). During later stages, some groups kept deliberating over who should get control. On many occasions, the student who claimed to understand the task best was awarded control (see Excerpt 8).

Excerpt 8
1  Frank  I want control
2  Frank  I can do better than Romy 😊
3  Romy  how do I pass it on?
4  Romy  yeah, right
5  Judith  okie!! Romy give it to Frank

Two types of episodes were observed to regain the common focus. One type pertains to gaining attention of a student who has not contributed to the discussion for some time, or wandered off to a different room without notifying his or her group members. As Figure 8 shows, such episodes were relatively scarce.

Group synchronization is another way to maintain a common ground. Group synchronization occurred when one student was working on his own for some time, and spontaneously reports back to
his fellow students. Such catch up planning also occurred when one of the other students asked for clarification. The latter instance of synchronization is illustrated in lines 1-3 of **Excerpt 7**

**Regulation of the learning task**
As the focus of this study is on (initial) planning and monitoring, these categories were used to classify the episodes concerning regulation of the learning task. Fourty episodes were coded as planning; 7 episodes were considered an instance of monitoring.

Despite the relatively high amount of planning episodes, the groups hardly engaged in meaningful planning activities. One reason is that 17 of the 40 planning episodes expressed students ignorance of the general approach to the learning task. As illustrated in **Excerpt 9**, no actual planning going on.

**Excerpt 9**
1 Romy what should we do?
2 Frank don't know
3 Judith ?

Another reason is almost complete lack of global planning. Except for Group 10, the groups did not go to the Meeting room to establish an overall approach to the learning task by formulating goals using the PC tool. Not did they discuss global planning through the chat. Instead, students adopted a kick and rush strategy.

Despite the absence of overall planning, all groups engaged in ad hoc planning. Such short-term planning episodes generally comprised a proposal for immediate action by one student and confirmations by the others. **Excerpt 10** shows a typical example of ad hoc planning.

**Excerpt 10**
1 Kate I think we should just use the simulation to compute how hard the tap should run
2 Becky sure
3 Kate ok??
4 Kate everybody agree?
5 Lisa yes
6 Lisa that's fine

As illustrated in **Excerpt 11**, Group 10 was the only group that actually elaborated on ad hoc planning proposals. Such commited dialogues were absent in the other groups’ discussions.

**Excerpt 11**
1 Kate make a table or something
2 Lisa ok, just make a table !
3 Becky we have to make a model first
4 Becky right?
5 Kate oh
6 Lisa but we have a model already
7 Lisa what do you think I have been doing !
8 Becky no I mean with those squares etc.
9 Kate she means with the shapes I think
10 Lisa do your best

Ad hoc planning further allows students to monitor their own activities, regardless of how low-level these may be. Yet virtually no evidence of such organization monitoring was found in the chat files. **Excerpt 11** shows a rare instance in lines 6 and 7 where Lisa reminds her group members that some modeling activities have already been accomplished.

While the lack of overall planning may have decreased the opportunities for goal monitoring, most ad hoc plans implied goals that could (or should) be monitored. Such monitoring occurred sporadically, however, although Group 10 showed how it could be done in lines 4 and 5 of **Excerpt 12**.

**Excerpt 12**
1 Lisa what should I change then?
2 Lisa gimme some hints!!!
3 Kate shouldn't we make a graph or something
4 Lisa first make sure it doesn't overflow
5 Lisa that was the point
Monitoring can also pertain to the students’ understanding of the learning task. Five of the 7 monitoring episodes were instances of such comprehension monitoring. Similar to the episode exemplified in Excerpt 9 these episodes merely expressed the students ignorance rather than their understanding of the subject matter.

4. Discussion

The aim of this study was to describe group activities within the initial stages of a Co-Lab session and to glean meaningful information regarding how students can be supported both planning and monitoring of their discovery learning session, particularly in the initial phases. This discussion will focus first on what the results of the navigational issues might mean for the use of Co-Lab and how that translates into support mechanisms within the environment, and secondly on the results of students regulation of their learning and it’s implications.

4.1 Navigation and Approaches to the Learning Task

The navigational issues discussed reveal that in the initial phases of a Co-Lab session groups will spend a majority of their time in lab experimentation and to a lesser degree in modeling activities. This may imply that students must first gain an understanding of the simulation properties via experimentation prior to being able to translate what they find into a workable model. None of the groups were able to attain a runnable model within their sessions, although most were able to attain a model sketch. Groups that took a more exploratory approach to the task evidenced more modeling activities than did the sequential groups.

The description of the lab work within the approach to the learning task section also points to the fact that initial experimentation in the absence of any further support to the contrary shows students engaging in what De Jong & Van Joolingen (1998) describe as an engineering approach to experimentation. This approach is characterized as one in which learners will attempt to create a desirable outcome instead of trying to understand the model (see also Schauble, Klobfer & Raghaven 1991).

Thus a tentative conclusion that can be drawn from this study is that students in the initial phases of working with Co-Lab need time and should be encouraged to engage in orienting experimentation and model sketching and take a more exploratory approach to discovery learning with Co-Lab before hopefully moving on to more systematic experimentation with hypothesis generation and model refining. This may also indicate that support for such activities as systematic experimentation, hypothesis generation and model refining may only be useful after students have engaged in sufficient exploration on their own of the environment. Within one to two hours all the groups had done some orienting type experiments in the lab and tried (with some exceptions) some initial model sketching. This may indicate that students need approximately one to two hours of such activities before more meaningful and systematic application of the discovery learning processes such as hypothesis making, experiment designing and application, model building and drawing conclusions from their work.

4.2 Regulation

Regulation of collaboration

As shown in the analysis of students’ regulatory activities, they mainly engaged in regulation of the groups collaboration. This may be typical of students working together for the first time, thus it may be expected that over time this type of regulation may decrease. It may also indicate that students need time to get oriented in working online using the control features of Co-Lab. A factor which may have contributed to the high degree of regulation of collaboration may also be the fact that students engaged in little to no global planning of how they would approach the learning task. It may be possible to say that if students started with a good working plan or had support in making one they may not have to engage in so much regulation of collaboration.


Regulation of the learning task  

Azevedo et al. (2003) conducted a series of studies on student’s self-regulation while learning about the circulatory system with a hypermedia environment. This research states that for good self-regulation to take place students need to be able to "analyze the learning situation, set meaningful goals, determine which strategies are effective in meeting the learning goal, evaluate their emerging understanding of the topic and determine whether the strategy is effective for a given learning goal. They need to monitor their understanding and modify their plans, goals, strategies and effort in relation to contextual conditions". As the analysis on regulation of the learning task shows, none of the groups engaged in anything more than ad-hoc planning, and their monitoring activities consisted mainly of expressions of comprehension failure. This result is not surprising given the lack of explicit support which students often require for self-regulation. Student learning with discovery learning environments shows that students do not engage in planning and monitoring effectively and that specific support is required to assist students in effective self-regulation (Azevedo et al., in press; Azevedo & Cromley, 2003; Green & Land, 2000; De Jong et al., 1998; White & Frederiksen, 1998; Hannafin & Land, 1997). The relatively low instances of planning and monitoring found in the analysis combined with the technical difficulties which prevented the students from utilizing the tool designed for such support may indicate that students will not spontaneously make a plan and engage in monitoring without specified support. Future studies need to examine the effectiveness of the Process Coordinator as a means of supporting students in planning and monitoring their inquiries.

Additionally no facilities were available for the students to keep track of what they were doing which may also have hindered monitoring activities. Another factor which may have influenced students lack of monitoring is the fact that they would need to go to another room to do this, i.e. the Meeting room. As seen in the analysis the students hardly visited the meeting room. A future design consideration may be to include the Process Coordinator in each room as a means of providing consistent support and to keep students focused.

4.3 Future research and the design of support  

Future research with Co-Lab needs to examine the effect which the Process Coordinator tool has on assisting students not only in taking a more fruitful approach to the learning task via taking time for orienting activities such as “playing” with the Lab, variable identification and model sketching but also to shows them the iterative nature of discovery learning. Towards this end an examination of the effect of this tool on student regulatory processes needs to be undertaken.

In the next study we intend to undertake this endeavor by examining how a fully specified Process Coordinator containing both top level goals and subgoals as well as specific hints and directions might impact student regulatory activities. Additionally evaluation, one aspect of the regulatory processes of students was unable to be determined due to the short duration of this study. Evaluation is a process which is undertaken by students to determine how well they understand the material being presented, in order to judge the course they have taken and the state of their own thinking (See Kluwe, 1987). In future studies a report tool function will be integrated into Co-Lab in order facilitate this important regulatory process. In order to adequately examine the impact and effectiveness of the fully specified Process Coordinator with report tool function a control group which has an empty Process Coordinator will be utilized.

References  


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# Appendix A: Coding schema for utterances

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive (C)</td>
<td>Utterances referring to (activities related to) the content of the learning task</td>
<td>Tank_level / Hole_diameter&lt;br&gt;My tank is half empty, yours too?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>We should specify the correct parameters in the simulation&lt;br&gt;Wait, this isn’t leading us anywhere&lt;br&gt;Let’s see what we’ve got so far</td>
</tr>
<tr>
<td>Regulative (R)</td>
<td>Utterances pertaining to the planning, monitoring and evaluation of the learning task</td>
<td>Hi guys, I’m in the Lab&lt;br&gt;Let’s go to the Hall&lt;br&gt;Pass on the control, please&lt;br&gt;What are we going to do next?&lt;br&gt;Shall I draft a model?</td>
</tr>
<tr>
<td></td>
<td>Utterances pertaining to the regulation of the collaboration</td>
<td></td>
</tr>
<tr>
<td>Affective (A)</td>
<td>Utterances expressing students’ feelings toward the task, the software, and the collaboration</td>
<td>This is too difficult&lt;br&gt;It’s a bit vague, isn’t it&lt;br&gt;Nice assignment!</td>
</tr>
<tr>
<td>Procedural (P)</td>
<td>Utterances concerning the technical operation of the environment and its tools</td>
<td>Press the button under the names&lt;br&gt;Can you see the simulation too?&lt;br&gt;Where can I find the process coordinator?&lt;br&gt;Stop scrolling !!!!!</td>
</tr>
<tr>
<td></td>
<td>Utterances expressing a request for help from the experimenter</td>
<td>Ask somebody then&lt;br&gt;</td>
</tr>
<tr>
<td>Off task (O)</td>
<td>Utterances not related to the learning task or the collaboration (social talk)</td>
<td>Look outside, its raining&lt;br&gt;</td>
</tr>
<tr>
<td></td>
<td>Uncodeable messages (chat talk)</td>
<td>f/gah/ko</td>
</tr>
</tbody>
</table>