
AC 2011-2262: THE EFFECTIVENESS OF STUDENTS' DAILY REFLECTIONS ON LEARNING IN AN ENGINEERING CONTEXT

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The Effectiveness of Students' Daily Reflections on Learning in Engineering Context

Reflection is a significant cognitive process to enhance students' learning outcomes and/or performance. Studies have shown the value of learners reflecting on what they have done, processed or engaged in so far.¹⁻⁸ The use of questions, prompts, or use of reflection as a form of feedback have been used to advance reflective processes in domains such as nursing education, teacher education, and science education.⁹⁻¹¹ However, relatively few of the above mentioned studies investigated the importance of reflecting on confusing points instead of reflecting on what is understood, and none of the studies were conducted in an engineering context.

This study investigated the relationship between engineering students' daily reflections about material they were unclear on and their learning of various introductory materials engineering science concepts. Materials science engineering students were asked to reflect on the "muddiest points" of class content at the end of each class for an entire semester. Our primary goal was to evaluate whether reflection about confusing points supported learning.

We propose that the nature of student reflection in this study is similar to Boud and Colleagues' conception, that "reflection is an important human activity in which people recapture their experience, think about it, mull it over and evaluate it."¹² In order to reflect on what was confusing in a lecture, students need to process prior knowledge and experience as well as new knowledge. In addition to thinking about what they heard or did in class, students need to critically assess and identify the topics, examples, or concepts that were confusing and those which were clearly understood. Therefore, when students are truly reflecting, they are monitoring what they know and do not know.¹³

During the monitoring process described above, reflection is also a constructive activity that utilizes creative cognitive processes such as reorganizing information or integrating new and old knowledge. These processes need to occur so that students can render judgments about their understanding. Recently, Chi¹⁴ proposed the active-constructive-interactive hypothesis, which asserts that different types of overt learning activities have differential learning effectiveness because they are characteristically different and involve different cognitive processes. A review by Chi based on experimental studies in the learning literature revealed that although activities using active, constructive, and interactive modes of learning are better than *passive* learning, interactive activities are more likely to be better than constructive activities, which in turn are better than active activities. In addition, Chi and colleagues describe self-explanation, a process whereby students comprehend and learn information via the explanations they provide for themselves while studying it,^{15,16} as a type of *constructive* activity that shows clear learning outcome advantages when compared to both *active* and *passive* learning activities.^{14,17} Self-explanation is likely to be inherent in the process of reflection. We argue that, depending on the level at which it is conducted, the process of reflection can serve as an active, constructive, or interactive learning activity that may impact students' learning.

The purpose of this study was to examine the relationship between student reflections, categorized by deepness and quality of statements, and their learning outcomes. In the following section we will describe Chi's¹⁴ framework of *passive*, *active*, *constructive* and *interactive*

learning activities and relate it to characteristics of student reflections. The remainder of the paper will consist of the methods, analysis, results and discussion section of current study.

Being Passive

Being passive refers to a learning situation in which the learner is essentially not engaging in any overt activity related to the learning task.¹⁴ Some examples of passive activities include listening to a lecture, watching a video, or reading a text without engaging in any additional observable activity such as note-taking, highlighting, or pausing and rewinding media. No underlying cognitive mechanisms are proposed for this level of the taxonomy since it is unclear whether or not the learner is engaged in the learning task and whether or not learning is occurring. In this study, we classified the absence of student reflection about their muddiest point as being passive.

Being Active

Being active refers to students' engagement in overt activities that activate their own knowledge within, but not beyond, the boundaries of the desired content.¹⁴ Chi defines being active as doing something overtly rather than passively waiting for information or instruction while learning or studying. Examples of the active mode include: repeating sentences after hearing them, underlining or highlighting sentences while reading, pointing at sentences or part of a solution, copying and pasting text, copying the solution of a problem from the board while the teacher is solving it, or selecting responses from a list of choices as in matching tasks. In this study, we classified shallow and vague student reflections as active learning activities.

Being Constructive

Being constructive refers to students' engagement in activities that develop their knowledge and understanding of content in new ways, thus extending their knowledge beyond the level of that being studied.¹⁴ The characteristic difference between the constructive and active mode is that in the latter case, learners do not produce outputs that go beyond the given information. Some examples of the constructive mode include drawing a concept map, taking notes in a lecture, generating self-explanations, comparing and contrasting different circumstances, asking comprehensive questions, solving a problem that requires constructing knowledge, or justifying claims with evidence. Accordingly, in this study, we classified deep and novel reflections as constructive activities.

Being Interactive

Being interactive refers to two or more learners' engagement in activities that develop knowledge and understanding that extends beyond the level being studied. This is similar to the constructive mode, but the interaction of the learners in this situation enables them to creatively build upon one another's understanding in an innovative way.¹⁴ In this study, there was no opportunity for students to collaborate during their reflection time; thus this category was not utilized when classifying student reflections.

Methods

Participants

The sample for this study included twenty-seven undergraduate engineering students enrolled in an introductory materials science and engineering class in a large public university located in the southwestern United States. Twenty-two of the participants were male students and five were female students. The mean age of the participants was 19 with a range from 18 to 21 years old. Each student enrolled in the class had already completed a college level general chemistry class as a prerequisite. Participation in the project was voluntary and students were assured that their participation would have no effect on their grades.

Procedure / Data Collection

The materials science engineering students were asked to complete the ‘Points of Reflection’ questionnaire at the end of each class during the entire semester (See Appendix A). The analysis for this study focused only on students’ reflections about their ‘muddiest points,’ or their responses to the question, “what was confusing or needed more detail” (referring to content delivered in class on that day). We collected students’ daily reflections along with results of the pre and post unit concept tests and unit exams that were routinely administered by the course faculty. We examined data from two units of course content, *crystal structures* and *polymer structures*. Instruction for each unit consisted of four days of classes, giving us a maximum of four reflections per student for each unit. In total, we had more than 200 hundred student reflections for the analysis.

Data collected throughout the semester were identified using an anonymous ID that the students selected; researchers were not able to associate students’ anonymous IDs with their names until the last day of class. At that time, students were asked to link their name to their anonymous ID so that the researchers could obtain course exam results from the instructor. The purpose of using anonymous IDs was to maintain the confidentiality of students’ statements and, accordingly, maintain student objectivity in their daily reflections. Students used their anonymous IDs for concept tests, as these scores did not affect their course grade and faculty had no need to know students’ identity. Unit exam scores however, did affect students’ grades in this class and therefore could not be anonymous; these results became available to the researchers at the end of the semester when students matched their anonymous ID with their names.

Measures

Points of Reflection – This questionnaire asked students to reflect on their perceived most interesting point, their “muddiest,” or most unclear point, their “take away” point, or the one that would be most valuable to their needs and their future, and a “learning point,” or what they learned about how they learned (See Appendix A). The analysis for this study focused only on students’ reflections about their muddiest points, assessed by the question, “what was confusing or needed more detail.”

Learning Outcomes - The measures of learning for this study were unit pre and post concept

tests, and unit exams. Both of these measures were regularly used in this class by the instructor. The crystal structures concept test measured students' knowledge of the unit cell structure, the location of atoms in planes, and the close packing crystal structure directions where atoms touch for Face Centered Cubic (FCC) cell, Body Centered Cubic (BCC) cell, and Simple Cubic (SC) (See Appendix B for a sample concept test). The polymers concept test measured students' knowledge of internal structures of polymer objects and their atomic structures. Identical tests were used as pre and post concept tests for each topic. Both concept tests and unit tests were graded by the class instructor or teaching assistants and those scores were used for our analysis.

Data Analysis

Students' daily reflections on their "muddiest points" were coded based on the deepness of their explanations. Figure 1 shows the flowchart that summarizes our coding schema. Our coding schema for the reflections followed an ordinal scale of 0-3 to indicate the degree of deepness or quality of reflections. A score of "0" was given if the student did not write anything as a muddiest point, or if the student's reflection was completely irrelevant to any class topic, discussion and/or assignment. A score of "1" was given to vague reflections, in which the student addressed course content, but simply restated one of the broad concepts or titles from a slide. This category also included statements referring to class organization or any course assignment. For example, the following statement, "the homework - I don't know how to figure it out because it is not in the book" was placed into this category. A score of "2" was given to general reflections which were neither deep/detailed statements nor simple repetitions of slide titles. For example, one student wrote "how to draw unit cells" as a muddiest point; this was not a simple or broad statement like a repetition of a slide title. However, it was still difficult to ascertain whether drawing a unit cell statement was actually referring to drawing directions or planes in a unit cell, or drawing a particular sort of cubic unit cell such as a BCC or a FCC unit cell. Thus, it was coded as general reflection due to its ambiguity. Finally, a score of "3" in our coding schema referred to deep/specific reflection statements. An example of a reflection that was scored in this category was "computing length, edges and atomic packing factor for FCC" This reflection was very specific about the student's area of concern.

We also considered the deepness of students' reflections to be indicative of the degree to which the reflections were relatively active or constructive. Using Chi's¹⁴ framework, student reflections in our study could be classified as active or constructive processes based on the details of the reflection and the cognitive processes that could be identified as being utilized. For example, after the first lecture of a crystal structures class, one student wrote "unit cells" as the muddiest point, whereas another student from the same class wrote "how type of the crystal structure affects strength of a material" as the muddiest point. The first reflection is a brief and shallow statement compared to the second reflection. Also, the first reflection is basically a restatement of one of the very broad concepts that was already presented in the lecture, which represents active learning, whereas the second reflection is a unique statement that links a concept from the lecture (i.e. crystal structure) to another concept that was not presented in that lecture (i.e. strength of material), which indicates more constructive learning. Overall, our coding schema with the ordinal scale of 0-3 not only indicated the degree of deepness or quality of statements but also related to the constructive nature of students' reflections.

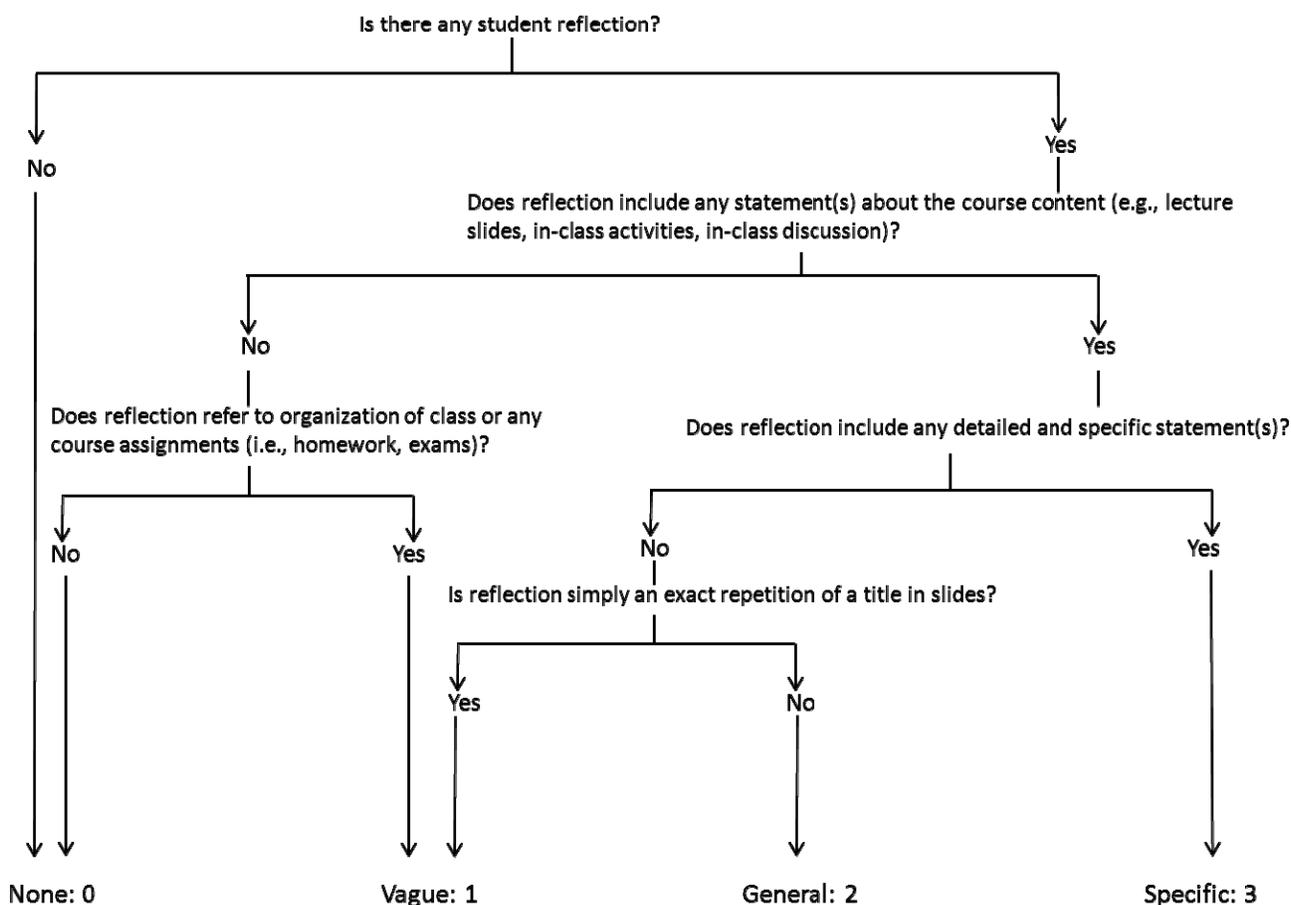


Figure 1: Coding schema used for the analysis of students’ reflections on muddiest points.

After coding each student reflection based on our schema, a total reflection score for each student was calculated by adding these scores. Then, a mean reflection score for each student was calculated by dividing the total reflection score for each student by the number of reflections she made. This averaging was particularly important because some students were absent some days and/or sometimes left the muddiest point questions blank. Adjusted gain scores were then calculated for concept tests. Adjusted gain scores (also known as g scores) were computed by dividing students’ actual gain scores from the concept tests (post concept score minus pre concept score) by their potential gain scores (maximum score possible minus pre concept test score). This formula indicates how much students gain relative to the amount possible that they could have gained from pre to post concept test.

To answer our research question regarding the relationship between student reflections about their muddiest points and subsequent learning outcomes, we calculated bivariate correlations between students’ average reflection scores and their gain scores on the pre-post concept tests, as well as their unit exam scores. The analysis was completed independently for each content area (crystal structures and polymers).

Results

Our analysis showed a significant positive correlation between the quality of students' daily reflections and adjusted gains scores based on the *crystal structures* pre and post concept tests, $r(25) = .47, p < .05$. In other words, students whose reflections on muddiest points involved more detailed explanations suggesting more constructive learning also showed greater progress toward mastery on concept tests than the students whose reflections were more shallow. However, there was no significant correlation between the quality of students' daily reflections and the unit exam scores. For the *polymers* unit, there was a significant correlation between students' average muddiest point scores and their percentage correct of the *polymer structures*-related questions on the unit test, $r(22) = .54, p < .01$. The students who were able to articulate their uncertainties about course material in more detail were also ones who scored higher on the unit exam in general. However, there was no significant correlation between students' average muddiest point scores and their pre-post concept test gain scores for *polymer structures*.

Discussion

Our research question concerned the relationship between the deepness and quality of students' reflections about their muddiest points and their learning outcomes. In other words, did students whose reflections were more detailed and constructive also do well in measures of performance? Our results provide some evidence to suggest that this is true. In the crystal structures unit, the quality of students' reflections was significantly related to their progress toward mastery on the concept tests, although it was not significantly related to their scores on the unit test. In the polymers unit, the quality of students' reflections was not significantly related to their gain scores calculated from the pre-post concept tests, although it was significantly related to their scores on the corresponding unit exam questions. These differences may be explained by multiple factors, among which are the diversity of content covered per unit, the similarity of pre-post concept tests or unit exam questions to the concepts addressed in student reflections, the amount of student effort expended on evaluation measures, and the phrasing of the question used to prompt student reflection. If the units that were evaluated contained many diverse concepts, it is possible that students' muddiest points and hence their reflections did not match the concepts that were tested, which might result in the nonsignificant relationship between the two variables despite the fact that learning may indeed have occurred. Future research might attempt to target evaluation of students' learning at the same concepts that were articulated as their muddiest points. Additionally, as mentioned previously, the pre-post concept tests did not factor into students' grades for the course. Students were aware of this and may not have expended their best effort to do well, particularly for more difficult content areas such as polymers. Lastly, the question that prompted students to reflect on their muddiest point, "what was confusing or needed more detail?" may not have suggested to some students that anything more than a shallow response was needed. For future data collections, the question has been revised to "describe what was confusing or needed more detail" to reduce this possibility.

In conclusion, our study results provided some evidence to support our hypothesis that the deepness and quality of student reflections about their trouble spots in understanding course content is related to their learning outcomes as evidenced by course performance. Our results suggest that this is a viable area for future research. Additional research is needed to further isolate and describe the relationship between these two variables.

Acknowledgements

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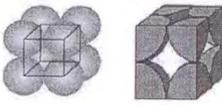
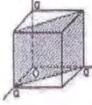
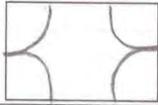
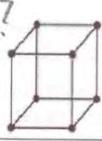
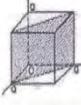
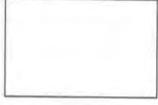
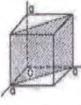
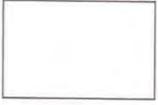
References

1. Baird, J., Fensham, P., Gunstone, R., & White, R. (1991). The importance of reflection in improving science teaching and learning. *Journal of Research in Science Teaching*, 28(2), 163-182.
2. Davis, E.A. (2003). Prompting middle school science students for productive reflection: Generic and directed prompts. *The Journal of the Learning Sciences*, 12(1), 91-142.
3. Katz, S., O'Donnell, G., & Kay, H. (2000). An approach to analyzing the role and structure of reflective dialogue. *International Journal of Artificial Intelligence in Education*, 11(3), 320-343.
4. Lee, A., & Hutchison, L. (1998). Improving learning from examples through reflection. *Journal of Experimental Psychology Applied*, 4, 187-210.
5. Moreno, R., & Mayer, R. (2005). Role of Guidance, Reflection, and Interactivity in an Agent-Based Multimedia Game. *Journal of Educational Psychology*, 97(1), 117-128.
6. Murphy, J. (2004). Using focused reflection and articulation to promote clinical reasoning: an evidence-based teaching strategy. *Nursing Education Perspectives*, 25(5), 226.
7. Scardamalia, M., Bereiter, C., & Steinbach, R. (1984). Teachability of reflective processes in written composition. *Cognitive Science*, 8(2), 173-190.
8. van den Boom, G., Paas, F., Van Merriënboer, J., & Van Gog, T. (2004). Reflection prompts and tutor feedback in a web-based learning environment: Effects on students' self-regulated learning competence. *Computers in Human Behavior*, 20(4), 551-567.
9. Dillon, J. (2007). Reflection, inspection and accountability. In J. Dillon & M. Maguire (Eds.), *Becoming a Teacher: Issues in Secondary Teaching* (pp. 98-111). New York, NY: Open University Press.
10. Pierson, W. (1998). Reflection and nursing education. *Journal of Advanced Nursing*, 27(1), 165-170.
11. Russell, T. (1993). Learning to teach science: Constructivism, reflection, and learning from experience. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 247-258). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.
12. Boud, D., Keogh, R., & Walker, D. (1985). Promoting reflection in learning: A model. In D. Boud, R. Keogh & D. Walker (Eds.), *Reflection: Turning experience into learning* (pp. 18-40): RoutledgeFalmer.
13. Tobias, S., & Everson, H. (2002). Knowing what you know and what you don't: further research on metacognitive knowledge monitoring. *College Board Research Report 2002-2003*.
14. Chi, M. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science*, 1(1), 73-105.
15. Chi, M.T.H., de Leeuw, N., Chiu, M.H., & Lavancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, 18, 439-477.
16. Chi, M.T.H., Bassok, M., Lewis, M.W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, 13, 145-182.
17. Fonseca, B. & Chi, M.T.H. (In press). The self-explanation effect: A constructive learning activity. In Mayer, R. & Alexander, P. (Eds.), *The Handbook of Research on Learning and Instruction*. Routledge press.

Appendix B: Crystal Structure Pre and Post Concept Test

Crystal Structure and Defect Concept Exploration

1. Fill in the blanks.

Crystal Structure	Unit Cell	Plane	Atoms on Plane	Describe where atoms touch
				Along the cube edge
			? 	?
			? 	?

2. Take a guess and sketch any pictures you can think of about what types of defects or imperfections could possibly occur in this crystal lattice.



3. When a material is heated to over half the temperature of its melting point atoms can start to move around. Take a guess and sketch a picture of how that might occur.