Examining the Flow of Ideas During Critique Activities in a Design Project

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Abstract: Peer critique activities in design projects give students the opportunity to share ideas, receive feedback, and revise their work. Critique can increase student feelings of ownership of science ideas and help students to distinguish between different ideas they may have about how things work. In this paper, we examine how students use their own ideas and ideas from a partner group to revise and improve a physical solar oven they have built using guidance from an online curriculum. We find that students fall into two groups: distinguishing ideas and adding new ideas. Within distinguishing ideas, students can further separated by whether or not they kept only their own ideas or also added the ideas from their partner group. We look at case studies to determine how these groups changed their ideas before, during, and after the critique activity.

Keywords: science, engineering, peer critique, technology, knowledge integration

Introduction

Design projects allow students to use science concepts to solve meaningful problems in topics such as energy efficiency. In addition to improving understanding of disciplinary concepts, middle school design activities engage students in the NGSS practices of engineering design (NGSS Lead States, 2013). We study a design project on solar ovens supported by an online curriculum. The project includes visualizations and interactive simulations to help students develop meaningful plans. Students draw on their scientific ideas and interpret the data collected using their physical artifacts to design and refine their solar ovens. We study how collaborative critique of student designs contributes to effective science learning.

Critique is common as a way to improve engineering designs (Krajcik, Blumenfeld, Marx & Soloway, 1994). Critique activities can guide students to justify their designs and identify flaws in their plans (Chang & Linn, 2013). Peer critique often succeeds when students discuss ideas together and justify their claims. This can help students clarify their ideas and reveal weaknesses in their understanding (Blumenfeld, Kempler & Krajcik, 2006). We examine how middle school students used their own ideas, others' ideas, and new ideas during critique of solar ovens. We then develop categories that are common types of student interactions during the peer critique activity in our curriculum.

By situating thinking in a social context, peer critique may increase student motivation (Wentzel, 1997). If students feel responsible for the success of their group, they may be more likely to engage and offer ideas. On the other hand, peer critique activities must be structured to ensure that all participants feel comfortable giving and receiving criticism (Scardamalia & Bereiter, 1994; Sato, 2015). Research on peer critique has shown the value of having students evaluate written work by their peers as a way to help students examine their own writing with a more critical eye (Black, Harrison, Lee & Marshall, 2003).

In addition to improving their designs, peer critique can help students develop a coherent understanding of underlying scientific concepts. According to the knowledge integration framework (Linn & Eylon, 2011), learning is achieved by first eliciting student ideas, then giving students opportunities to add new ideas and distinguish between these ideas. Peer critique provides an opportunity for students to express their ideas and hear new ideas from their peers. Students bring different prior experiences with them to the project, and can offer unique ideas (Matuk, Linn & Eylon, 2015). In a successful critique activity students will then distinguish between these ideas according to agreed-upon criteria. Students may be called upon to distinguish between their own ideas when developing explanations, but distinguishing the ideas of a group based on agreed-upon criteria may require further discussion to develop criteria.

Since students often receive feedback only from their teachers or other authority figures they may benefit from peer feedback that is worded more like their own thinking (Cole, 1991; Linn & Songer, 1991). In an environment where students feel comfortable sharing ideas and providing reasonable criticism, in addition to receiving feedback, students can develop general criteria for evaluating designs, which they may then apply to later activities (Clark et al., 2012). By building an awareness of what makes a good design, students develop greater agency and a sense of ownership over their designs and ideas.

However, it is often the case that students have difficulty establishing and applying appropriate, mutual criteria for evaluating ideas. If students have many ideas to distinguish, developing criteria for distinguishing could be quite a challenging task. This could be due in part to the fact that students may not practice critique often in the classroom setting. Numerous studies document the challenges faced by students when they are new to peer critique activities (e.g., Tsivitanidou, Zacharia, & Hovardas, 2011; Gan & Hattie, 2014; van Zundert, Könings, Sluijsmans, & van Merriënboer, 2012). In cases where students have not agreed upon criteria based upon underlying scientific ideas, they may focus on superficial features of designs. Furthermore, without criteria grounded in scientific concepts, students may feel reluctant to provide criticism, as it could be misinterpreted as a personal offense.

In previous work (McBride, Vitale, Applebaum & Linn, 2016), we saw mainly positive critiques ("Add more tinfoil") rather than negative ("use black paper instead of tinfoil"). This effect may be exacerbated if students are expected to engage in face-to-face, verbal critique. This could be because of the structure of the curriculum; students are given a new budget during the revision to add to their oven, so during the critique activity they may be trying to decide how to spend their new budgets. However, students may also find it easier from a social standpoint to give positive critiques rather than negative (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001).

In this study, students often seemed to provid feedback without scientific justification, providing a peer group with a new idea, but no rationale for that new idea. This could be because students were reluctant to provide explanations, they did not feel they had to provide an explanation, or fi they did provide and explanation during conversation, they simply did not write it down. In practice, engineers are often called upon to provide rationales for design changes. For professional engineers, providing rationales and being reflective is an important practice in improving design skills (Adams, Turns, & Atman, 2003; Schön, 1983). Rationales may be centered in the artifact and may also provide a way to understand and talk about dependencies in a complex project (Gruber & Russell, 1996). We introduce students to dependencies and tradeoffs by having them use a budget during the curriculum.

Types of student interactions during the peer critique activity could be categorized into groups using the knowledge integration framework. Two possible groups are "idea distinguishers", and "idea adders". In this curriculum, we aim to help students integrate their design choices with science concepts, so we consider the "integration" component of the knowledge integration framework to be specifically science and design integration. Ideally, peer critique activities will support students across groups in improving their practices of scientific idea integration, while also giving students the opportunity to add and distinguish ideas.

In this study, we examine how students' original ideas change and grow from their first ideas about revisions they will make to their final ideas. We will evaluate the extent to which groups maintain their original ideas, add new ideas, distinguish between ideas, and integrate ideas with scientific justifications. Based on our findings from this analysis, we can also inform future design of critique activities to encourage certain types of student activity, like providing justifications and rationale.

Methods

Participants and procedures

One 6th grade teacher and her 150 students participated in this study. Following individual pretest, the teacher assigned students to a total of 55 dyad or triad workgroups; students in this class often work together on group activities. Following curricular activities, students engaged in an individual posttest.

Curricular materials

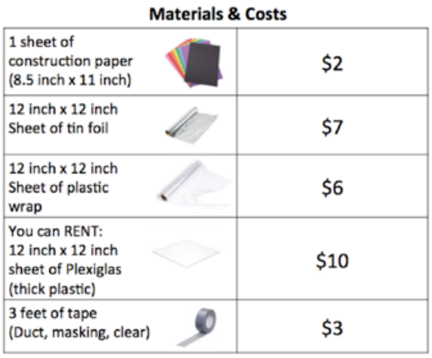
This study was implemented in a curriculum module entitled *Solar Ovens and Solar Radiation* (referred to as *Solar Ovens* in this paper). The goal of the unit is to familiarize students with the way energy transforms from solar radiation to heat through a hands-on project and interactive models, covering the modeling aspect of the Science and Engineering Practices of the NGSS, as well as the standards associated with energy, specifically standards related to the transformation of thermal energy (NGSS Lead States, 2013). Students engage with the curriculum online through WISE (Web-based Inquiry Science Environment), utilizing a variety of instructional and assessment tools (Linn & Eylon, 2011).

Students follow a design, build, test approach with two iterations. For added support for distinguishing between and reflecting upon ideas, we include explanation and critique activities between iterations. Prior to building, students engage in a series of design activities intended to make science concepts central to students' design plans. In a budgeting activity students are prompted to choose and justify materials they plan to use. Figure 1 shows the material and budget list. For their initial design, students are allowed to spend $20 on their materials (excluding the box). In later design revisions students receive an additional $13 budget. By limiting their access to materials, students are forced to consider the most important elements of their design. Following budgeting, students engage with an interactive virtual model to investigate various design options (e.g., materials), and familiarize themselves with underlying mechanisms (Wilensky, 1999). In addition to selecting materials and testing them in the virtual model, students are also prompted to draw pictures of their ovens and explain how energy transfer will occur in their oven. After building, students test the ovens using digital temperature probes that collect data and generate a graph in real-time. The physical ovens are tested under lamps with a common set of requirements so that results are comparable between trials and groups. After revising, building, and testing a second time, students in this class cooked marshmallows in their ovens. Table 1 displays the general layout and features of the *Solar Ovens* curriculum unit.

We specifically investigate the use of the critique activity that occurs between iterations of designing, building, and testing. In this activity, students were first asked to describe the changes they would make to their own ovens during the next iteration. Then, students were instructed to work with the group next to them to exchange ideas about the ovens. This activity required some facilitation from the teacher. Students were asked to give at least one idea to the group they were working with, and to take at least one idea from the other group. Students wrote these ideas in WISE during the activity. In the next activity, redesigning the oven, we asked students to describe the changes they would actually make to their ovens.

Table 1: *Solar Ovens* Curriculum Outline

Activity	**Description & Items of Interest**
Introduction to Solar Ovens	Elicit initial student ideas about energy transformation
Solar Radiation and the atmosphere	Energy comes as radiation from the sun; energy can be absorbed or reflected. Students use a simulation to investigate energy.
Solar Radiation and Greenhouse Gases (GHGs)	Describes how energy interacts with greenhouse gases. Students use a model to investigate how addition of GHGs impacts energy.
Model Activity	Students use an interactive model to investigate how radiation works in a solar oven
Design, Build, Test 1	Design oven under budgetary constraints using a draw tool, build, test under a heat lamp using a temperature probe to collect data
Reflect & Critique	Students think about changes they will make to their oven and engage in critique activity with other student group
Design, Build, Test 2	Students reflect on what was learned from the first iteration; use new budget constraints to repeat process
Reflect	Students describe how their solar ovens work using energy from the sun; make connections between solar ovens and the atmosphere


Materials & Costs

1 sheet of construction paper (8.5 inch x 11 inch)	$2
12 inch x 12 inch Sheet of tin foil	$7
12 inch x 12 inch Sheet of plastic wrap	$6
You can RENT: 12 inch x 12 inch sheet of Plexiglas (thick plastic)	$10
3 feet of tape (Duct, masking, clear)	$3

Figure 1. Materials and cost list for Solar Ovens curriculum

Analysis materials

We examined four items for each group. These items come from the reflection stage, the critique activity, and the very first activity during the redesign process. These items are:

1. *Reflect*: Students describe the changes they wish to make during the redesign of their oven

2. *Take*: Students write the idea(s) they received from the group they worked with
3. *Give*: Students write the idea(s) they gave to the group they worked with
4. *Redesign:* Students describe the changes they wish to make during the redesign of their oven

Analysis approach
Our analysis approach for these items included developing a list of ideas students mentioned in any of their four responses. This list of ideas was then grouped into several categories that encompassed the majority of student ideas. We used the shortened list of ideas to code students' responses for the presence of ideas in order to track where ideas occurred within these four items. The shortened list is made up of the ten student ideas in Table 2. It would be useful to also have student reasoning for their design decisions, but many students did not provide reasoning, though the question specifically asked for it. Many students may have provided reasoning during the conversation that took place during the peer critique activity, but that reasoning was not recorded.

Table 2: Student idea categories and counts during each activity

Student Ideas	Reflect	Take	Give	Redesign	Total
Add aluminum foil	22	12	8	25	67
Add tape	5	0	3	10	18
Add more paper (black or white)	12	9	13	17	51
Add plastic wrap	9	4	6	10	29
Add or adjust reflective flap	16	13	9	11	49
Add Plexiglas	6	4	1	5	16
Tighten the plastic wrap over the top of the oven	3	3	3	3	12
Patch holes anywhere in the oven	4	4	6	1	15
Adjust or add a flap to insert food or a temperature probe	3	5	7	1	16
Adjust box construction (size, shape, structure, etc.)	2	2	0	2	6

Results
Overall, we found that students wrote more ideas about their own ovens than peers' ovens. Across the 55 groups, students wrote an average of 1.55 ideas in the *reflect* item and 1.60 ideas in the *redesign* item, while only writing an average of 1.06 ideas in each of the *give* and *take* items. The greater number of ideas written for *reflect* and *redesign* are not surprising since students are more familiar with their own designs and ovens than the designs of other groups.

We next break down the flow of ideas from each item to the next in Table 3. In this table, we look at the interaction between each possible pair of items.

Table 3: Flow of ideas between items

	Items	# Ideas Carried Over
Groups use ideas from their peer group	*Reflect* to *Take* (1 to 2)	24
	Take to *Give* (2 to 3)	4
	Take to *Redesign* (2 to 4)	17
Groups use their own ideas	*Reflect* to *Redesign* (1 to 4)	35
	Reflect to *Give* (1 to 3)	13
	Give to *Redesign* (3 to 4)	23

Taking a closer look at whether students took their own ideas (*reflect*) or the ideas they received from the other group (*take*) with them to the redesign stage, of the 53 groups, 9 groups (16%) kept ideas in the *redesign* item from both the *reflect* and *take* items, 14 groups (25%) only kept ideas from *reflect* item in their *redesign* response (no ideas carried over from *take),* 2 groups (4%) only took ideas from the *take* item in their *redesign* response (no ideas carried over from *reflect)*, and 22 groups (40%) did not use ideas from their *reflect* response or the *take* item in their *redesign* response. There were 8 groups (15%) that did not mention any specific ideas in their *redesign* response (e.g. "*Well, we will use materials that will effect the box the most, so we only use 10 dollars."*).

This interaction between ideas students generated themselves and those generated by another group shows that some students seem to keep only their own ideas, while others seem to engage in idea generation during the critique activity. Generating new ideas during the critique activity may help these students to generate more new ideas for themselves later in the design process.

Examining some of the other interactions between items, we see that students often carried ideas over from those that they gave to another group (*give*) to their own redesign. This happened 24 times (22 groups carried over one idea, 1 group carried over two ideas). This signals that having students generate ideas for another group is a useful activity for helping students to add more ideas to their repertoire for their own solar oven. Students generally did not carry over ideas from the *take* item to the *give* item. There were 4 ideas carried over, but in this case 3 of the ideas were carried over by the same group, with only one other group using the same idea for both *give* and *take* items.

During the analysis of this data, we also noticed that students did not often give negative critiques to other groups. However, this may be because of the structure of the unit. During the critique activity, students are thinking about what they can now add or change about their oven, so these are the types of critiques they get and give. This may also reflect a difficulty students have in giving their peers negative feedback, possibly because they do not yet consider themselves experts on the topics covered in the unit.

Students seem to fall into one of two categories: idea adders or idea distinguishers. Idea distinguishers can then be further broken down into students take ideas from others or those who keep only their own ideas. Students fall into the group of idea adders if they did not use any of their own previous written ideas or the ideas given by their peer group during *Redesign*. Students fall into the group of idea distinguishers (keep) if they kept only their own written ideas at *Redesign*. These students may not have liked the idea given to them by their peer group, the given idea may have been incorrect, or the budget may have been prohibitive. In any of these cases, however, the students distinguish between ideas and choose to carry forward with their own ideas. Students in the group of idea distinguishers (take) use ideas given to them by their peer group in *Redesign*. They can do this in conjunction with keeping their own written ideas from *Revise*. We discuss each of these four categories further through case studies.

Table 4 shows the breakdown of how many groups fell into each category from our data. In the knowledge integration framework, students should also integrate their ideas together. In this context, integration is considered integrating a design idea with reasoning that comes from science concepts. Only 14 groups integrated their design ideas with science reasoning in *Redesign*, even though the question specifically asked for reasoning. These groups were also spread across our three categories.

Table 4: Number of groups in each category and groups who integrate design ideas with science concepts

Category	**# Groups / (Total)**	**# With Integration**
Idea Distinguishers (Take)	17 / (55)	6
Idea Distinguishers (Keep)	14 / (55)	4
Idea Adders	23 / (55)	4

Case studies

To further illustrate the results presented above, we use three case studies. Each of these cases offers a different view of how students use ideas presented during the critique activity. We will compare where ideas present in the last activity, *Redesign*, initially emerge. We specifically examine each of the following scenarios: groups who kept their own ideas and took ideas from their peer group, groups who kept only their own ideas, and groups who did not use any of their original ideas or the ideas from their peer group. Important parts of the responses are underlined.

Case 1: Idea Distinguisher (Take)

In this case, the pair of students both kept their original ideas (*reflect*) and took the ideas given to them by their peer group during the critique activity (*take*). This type of case happened in 17 out of 55 groups. Each item answered by the pair is shown below:

- Reflect: *"We could improve our solar oven by making the tin foil flaps bigger."*
- Take: "*One idea that we got was to put black paper all around the inside of the box."*
- Give: "*One idea I gave the group is that they should put a tin foil flap."*

- Redesign: "*we will buy black paper and more tin foil. The black paper is to absorb the heat inside the oven. The tin foil is to make a larger flap to direct the rays from the sun to the oven."*

While students certainly write their own ideas for revising their oven in the *reflect* item, the nature of the project is such that students can watch other students in the classroom test their ovens and gain new ideas simply from looking around the classroom. Many of the *reflect* ideas likely come from watching other students, in addition to a group's own ideas. This group starts out with an idea about improving the reflector flaps on their oven. This group got the idea of putting black paper on the inside of their box during the critique activity. When the group was asked how they would redesign their oven, they said they would use both ideas to improve their oven. Since each group has a limited budget, this was an interesting case in which the group was able to add materials to their budget to fulfill an idea given to them by another group. Another common occurrence seen in the *give* item was groups giving their own ideas to the other group. This happened in this case as well, with the group suggesting to their peer group that they "*should put a tin foil flap"*. This group also exhibited integration, integrating their design idea in *Redesign* with science reasoning.

Case 2: Idea Distinguisher (Keep)

In this case, the pair of students kept their original ideas (*reflect*), but did not take any new ideas *(take)* into the *redesign* activity. This type of case was fairly common, happening in 14 out of 55 groups. Each item answered by the pair is shown below:

- Reflect: "*We can add plexiglass and still have $3 dollars left if we get the additional $10 button."*
- Take: "*One idea that they gave us is that they put black paper on every side, including the bottom of their flap."*
- Give: "*They could use plastic wrap or plexiglass on top and ad a hole that can put the smore in it easier."*
- Redesign: "*We will add plexiglass and tape to keep more heat in."*

In this case, the group began the critique activity with the idea that they would revise their oven by adding Plexiglas (*reflect).* This also included a discussion of their budget. The Plexiglas cost the students $10, their whole budget. However, it seems that the students did not utilize their entire budget during the first round of building. It was common in this classroom for the teacher to allow the students to carry over any additional budget to the second iteration of building. The group mentions that they have $3 left in their budget. During the critique activity, the students are given the idea of using black construction paper on all surfaces of the oven; construction paper costs $2/sheet, so it is within their remaining budget to add some construction paper. However, the group decides to use their new budget to add Plexiglas and tape, sticking with their original idea from the *reflect* item. Again, this group offers their own idea to their peer group in the *give* item: to use Plexiglas. While students are giving ideas to other groups that are relevant to improving the function of the oven, we would like to improve students' critical thinking in order to provide more relevant critiques to other groups.

Case 3: Idea Adders

In this case, the pair of students did not keep their original ideas (*reflect*) or take the ideas from their peer group in the critique activity (*take*). This type of case was most common in our data, occurring in 23 out of the 55 groups. Each item answered by the pair is shown below:

- Reflect: "*we could have had the alumnin foil flap better postioined. Also Maybe the plastic wrap could have been tighter."*
- Take: "*we got the idea to use plexiglas insted of plastic wrap."*
- Give: "*was to use tape to cover the holes."*
- Redesign: "*We will add more black paper and touch up on some things that looked bad."*

This type of case was the most common in our data. In the *reflect* item, the group wrote about changing the position of their reflector flap and tightening their plastic wrap. Their peer group gave them the idea of using Plexiglas instead of plastic wrap as a cover on their oven (*take*). However, in the *redesign* item, the group wrote about something completely different, adding black paper. In addition, the group did not give this idea about black paper to their peer group during the critique activity (*give*). While it is difficult for us to say exactly where this idea came from, this example illustrates how the critique activity can help students think about new and different ideas. This group both had and was exposed to many ideas during the course of these four items, and was able to then think of even more new ideas for their redesign. While the group may not have provided scientific justification for their ideas yet, this still fits with the underlying knowledge integration framework; students need to add ideas to their repertoire in order to later sort those ideas.

Conclusions and implications

This work offers a view into how students are using critique activities during their work in hands-on science projects, and offers a way to categorize how students use the peer critique activity to add and distinguish between new ideas.

We provide support for peer critique activities in our curriculum through face-to-face interaction with peer groups. During this direct interaction, students were able to engage in further conversation and often had to provide scientific justifications for their critiques to their peer groups. This resulted in the vast majority of the critiques during this project being about scientific and design choices, rather than superficial choices (e.g., decorative features).

The results of our data analysis help to show the benefits of using critique activities during design projects. While some students will still utilize only their own, preexisting ideas, many other students add ideas during the critique activity. The students who add ideas may combine their ideas with ideas from other groups, come up with completely new ideas after the critique activity, or give up on their ideas in favor of the ideas from their peers. From a creativity perspective, as well as a knowledge integration perspective, it is beneficial for students to be exposed to many different types of ideas. Students may learn more about the scientific implications of their design choices by having to sort through multiple ideas for revising or creating their designs.

Understanding how students use ideas from the peer critique activity to help develop new ideas or criteria for distinguishing between ideas helps to inform how we can design curriculum to encourage better practices for students.

One shortcoming of this curriculum and study was the lack of scientific reasoning given by students in their explanations for their design choices. In future uses of the Solar Ovens curriculum, students will be prompted for their design choice and their scientific reasoning separately (instead of in the same question prompt). This data provided us with useful information showing that students do not often want to provide reasoning or what they may see as extraneous explanation, but in the future we would like to also be able to better understand students' reasoning and help them to develop their explanation and argumentation skills.

References

Adams, R. S., Turns, J., & Atman, C. J. (2003). Educating effective engineering designers: The role of reflective practice. *Design studies*, *24*(3), 275-294.

Barron, B. (2003). When smart groups fail. *The journal of the learning sciences*, *12*(3), 307-359.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of general psychology*, *5*(4), 323.

Black, P., Harrison, C., Lee, C., Marshall, B., & Wiliam, D. (2003). The nature of value of formative assessment for learning. *Improving schools*, *6*, 7-22.

Blumenfeld, P. C., Kempler, T. M., & Krajcik, J. S. (2006). *Motivation and cognitive engagement in learning environments*.

Clark, D. B., Sampson, V., Chang, H. Y., Zhang, H., Tate, E. D., & Schwendimann, B. (2012). Research on critique and argumentation from the technology enhanced learning in science center. In *Perspectives on Scientific Argumentation* (pp. 157-199). Springer Netherlands.

Chang, H. Y., & Linn, M. C. (2013). Scaffolding learning from molecular visualizations. *Journal of Research in Science Teaching*, *50*(7), 858-886.

Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of educational research*, *64*(1), 1-35.

Cole, D. A. (1991). Change in self-perceived competence as a function of peer and teacher evaluation. *Developmental Psychology*, *27*(4), 682.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences*, 13(1), 15–42.

Gan, M. J., & Hattie, J. (2014). Prompting secondary students' use of criteria, feedback specificity and feedback levels during an investigative task. *Instructional Science*, *42*(6), 861-878.

Gruber, T. R., & Russell, D. M. (1996). Generative design rationale: Beyond the record and replay paradigm. *Design rationale: concepts, techniques, and use*, 323-349.

Krajcik, J. S., & Blumenfeld, P. (2006). Project based learning. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. New York: Cambridge University Press.
Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. *The elementary school journal*, 483-497.
Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration. Routledge.*
Linn, M. C., & Songer, N. B. (1991). Teaching thermodynamics to middle school students: What are appropriate cognitive demands?. *Journal of research in Science teaching*, *28*(10), 885-918.
Matuk, C. F., Linn, M. C., & Eylon, B. S. (2015). Technology to support teachers using evidence from student work to customize technology-enhanced inquiry units. *Instructional Science*, *43*(2), 229-257.
McBride, E.A., Vitale, J.M, Applebaum, L.R., Linn, M.C. (2016) Use of Interactive Computer Models to Promote Integration of Science Concepts Through the Engineering Design Process. In *Proceedings of the 12th International Conference of the Learning Sciences.*
NGSS Lead States. (2013). Next Generation Science Standards: For States, By States.
Sato, M. E. (2015). Designing Critique for Knowledge Integration (Doctoral Dissertation). Retrieved from ProQuest Database. (Accession No: 3733349)
Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, *3*(3), 265-283.
Schön, D. A. (1983). *The reflective practitioner: How professionals think in action* (Vol. 5126). Basic books.
Tsivitanidou, O. E., Zacharia, Z. C., & Hovardas, T. (2011). Investigating secondary school students' unmediated peer assessment skills. *Learning and Instruction*, *21*(4), 506-519.
Van Zundert, M. J., Könings, K. D., Sluijsmans, D. M. A., & Van Merriënboer, J. J. G. (2012). Teaching domain-specific skills before peer assessment skills is superior to teaching them simultaneously. *Educational Studies*, *38*(5), 541-557.
Wentzel, K. R. (1997). Student motivation in middle school: The role of perceived pedagogical caring. *Journal of educational psychology*, *89*(3), 411.
Williams, L., Wiebe, E., Yang, K., Ferzli, M., & Miller, C. (2002). In support of pair programming in the introductory computer science course. *Computer Science Education*, *12*(3), 197-212.
Wilensky, U. (1999). {NetLogo}.

