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ABSTRACT

How can students develop shared criteria for problems that have no "right" answer? Ill-structured problems of this sort are called design problems. Like portfolio projects, these problems are difficult to evaluate for both teachers and students. This investigation contrasts two methods for developing shared criteria for project evaluation. Elements of self-criticism and peer review appear in both methods with levels of collaboration altered between the two conditions. The investigation used the Scaffolded Knowledge Integration (SKI) framework to guide the curriculum design. The two approaches were an autonomous condition in which students worked in pairs on a single design and then critiqued their own designs and a collaborative condition in which students create separate initial designs and then merged them into one. Eighth graders (n=148) used the Knowledge Integration Environment (KIE) to design passive solar energy efficient houses for the desert. Results show that in both conditions students develop shared criteria in the sense that, as a group, they evaluate pieces of evidence to support their designs. However, the collaborative condition makes the need to evaluate alternatives visible to students. This increase in visibility may partially account for the increase in principled selection among alternatives in the collaborative condition. This effect appears to be strongest for students who do not distinguish between ideas such as heat and temperature. Ultimately, building shared criteria, through collaboration for some students and through autonomous activities for others, can scaffold students as they become more autonomous critical thinkers. (Contains two figures.) (SLD)

Using KIE to Help Students Develop Shared Criteria for House Designs

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Using KIE To Help Students Develop Shared Criteria For House Designs

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How can students develop shared criteria especially for problems that have no "right" answer? Such ill-structured problems are typically called *design problems*. They can be identified by their open-endedness, the problem structuring they require, and the iterative refinement that characterizes solution paths.. Like portfolio projects, these problems are difficult to evaluate for both teachers and students. Often success is measured by the relative fit between the solution and the criteria selected to define the problem. Therefore if students select different criteria, a uniform metric for evaluation cannot be used. As educators and researchers, we need to encourage educational approaches that help students develop shared criteria not just for design projects but for analysis of scientific methods.

Objective

This investigation contrasts two methods for developing shared criteria for project evaluation. Elements of self-critique and peer review appear in both methods with the levels of collaboration altered between the two conditions.

Theoretical Perspective

The investigation uses the Scaffolded Knowledge Integration (SKI) framework (Linn, 1995) to guide the curriculum design. One aspect of this framework involves making thinking visible. Vygotsky's social theory of learning which suggests that we learn through the internalization of observed behavior guided the design of the collaborative condition. We anticipate that the development of shared criteria can occur through a process of peer review that is reinforced or reinterpreted through self-critique. In addition, the opportunity for self-analysis provides a chance for students to become more autonomous learners.

To help student develop shared criteria, we use several approaches to make thinking visible. For example, students complete worksheets designed to encourage iterative refinement of the problem. These worksheets involve specifying temperature regulation approaches, selecting relevant structural aspects of the dwelling (e.g., windows, roofs, walls, materials, color, and orientation), creating functional representations of the heating-cooling cycle, and drawing graphical representations of heat flow at different times of day. Other approaches we use include an online collaborative search page for pooling comments about Internet resources and an online peer review form for final designs.

This paper focuses on the interaction between two of these solutions that have resulted in radical revisions to designs and by extension the criteria used to evaluate them. These two approaches are: (a) an autonomous condition where students work in pairs on a single design and then critique their own designs and (b) a collaborative condition where students create separate initial designs and then merge them into one. Our hypothesis is that students that are unable to generate design alternatives will have trouble with self-critique. Collaboration can help these students expand their problem definition and build shared criteria by making thinking visible through self-explanation.

Methods

In this experiment using the Knowledge Integration Environment (KIE), eighth graders (N=148) design passive-solar, energy efficient houses for the desert. The house design project is a capstone activity following a semester on thermodynamics. Prior to the house design project, students gain experience using scientific principles to make predictions about experimental situations. They critique evidence based on its reliability, credibility, and source helping prepare them to search the Internet for evidence to support their house designs.

Results & Discussion

The majority of the teams (~90%) completed the two-week project with many of the students coming in during lunch and after school to work on their designs. Students in the collaborative condition tended to consider alternatives more carefully. Beyond the experimental effects, factors such as the student's disposition and the nature of the interaction between partners contributed to the success of the projects.

Overall Analysis. Overall, there was a significant correlation ($F(148)=4.787$, $p<.001$) between the number of alternatives considered and the innovation of the design. These numbers provide an indication that innovation may be linked to the rate of revision.

Alternatives Considered. Surprisingly, students who had to merge designs in the collaborative condition did not consider more design alternatives than those in the autonomous condition. However, the number of design alternatives considered and discarded based on scientific principles (or evidence found on the Internet) was higher for the collaborative group than for the autonomous group.

Experimental Effects. Initial coding of pre and post-tests suggest that the collaborative condition benefited students with confused terminology for the heating and cooling cycle in the desert (e.g., students that did not differentiate between heat and temperature or insulation and conduction.) The autonomous condition benefited students with descriptive but unmechanistic explanations (e.g., "it takes longer for the ground to heat up.") Unfortunately, it is difficult to assign causality given the complex nature of social dynamics and the numerous factors involved in classroom activities.

Information Constraining Designs. An additional factor, the range of available information, constrains the process of selecting criteria. In the majority of cases where students introduced new criteria for a design, information from our online house design library or the Internet drove the selection process. Figure 1 shows the two initial designs and the final design for a group that refined ideas about ventilation by adding a retractable solar panel. The house rotates in the evening so that the passive solar panels, colored black for optimum energy conversion, can receive light from the setting sun.

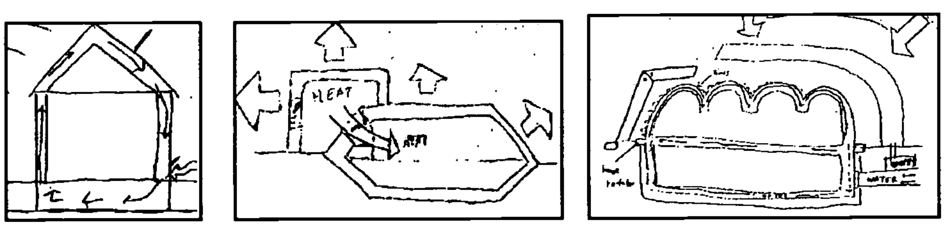

Figure 1. Refinement of a ventilation strategy.

The students looked first for information on windows. Then realizing that they were the weakest link in most houses, they considered additional alternatives such as using trees to shade the house or solar panels as walls. The solution they reached was to raise the solar panels above the house and circulate the water through the basement for radiant heating.

Knowledge Building. More qualitative measures of the effect of collaboration on the design process indicate that students respond differently to peer review depending on their initial level of understanding and their methods of self-explanation. For example, one pair of students in the collaborative condition started with similar ideas about why the outside temperature in the desert peaks before the ground temperature. Specifically, they believed that the sand or dirt took a while to absorb the heat energy. In the pre-test, neither student distinguished between heat and temperature. However, one student attempted to explain situations by referring to previous labs and prototypes:

> I will use the burner example again. If you turn a burner on high - then it heats up very quickly. But because it is heating up a material it takes longer for the heat to filtrate through a substance and therefore raise the temperature. So if the burner was on high - then you would have to wait awhile before you see the water start to bubble or heat up.

The students located two Internet sites that lead to their consideration of light converting to heat energy as a possible factor: a site showing the reflectance index for roofing materials and a site showing how location affects climate. The evolution of their designs from initial sketches through the final design appears in figure 2.

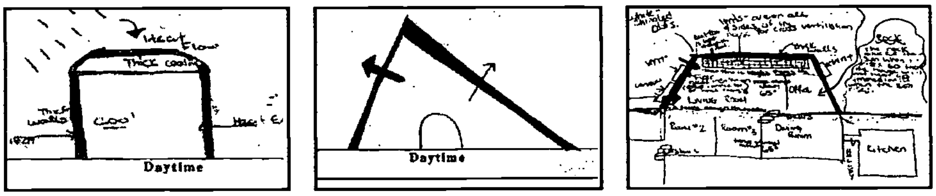

Figure 2. Merging of two students drawings into a final design.

Structurally the students have combined their designs incorporating new features based on the available information. There is a rock to the east of the house to reduce direct sunlight in the morning. The color of the house is white "because in a lab that we did, we learned that white scatters light more than a black house would. This is especially good for houses in the desert because there is a lot of light that would change to heat energy."

In the final design report, the pair of students refers to previous experiences and scientific principles to explain their reasoning. Closer examination of the post-test reveals that the students, while having similar experiences, exhibit different degrees of knowledge building possibly due to the way in which they are processing information (see Chen, Burtis, & Bereiter, 1997.) The student that is trying to explain things in terms of prototypes has shifted her explanation for why the outside temperature peaks before the ground temperature:

> The ground temperature heats up slower than the air temperature because the heat energy has to flow through the air before it reaches the ground. It also takes time for the ground to absorb the heat energy. Like if you shined a light bulb onto a test tube of sand – the sand wouldn't heat up to its peak temperature in a half of a second, it would take time.

While this student has moved from a conduction to a light conversion model, the other student does not consider light as a factor in the equation. Granted this problem is complex and dependent on a wide range of factors. However, the interesting dimension of the problem is that collaborative work has benefits and trade-offs that appear to be linked to the students' previous level of understanding and to their methods for explaining phenomena.

Educational Implications

We are just beginning to understand the benefits and trade-offs of collaboration and the role it plays in building shared criteria. In both conditions, students develop shared criteria in the sense that, as a group, they evaluate pieces of evidence to support their designs. However, the collaborative condition makes the need to evaluate alternatives visible to students. This increased visibility may partially account for the increase in principled selection among alternatives in the collaborative condition. This effect appears to be strongest for students that do not distinguish between ideas such as heat and temperature. Ultimately, building shared criteria, through collaboration for some students and through autonomous activities for others, can scaffold students as they become more autonomous critical thinkers.

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