SMILE: Promoting Transfer in a Design-Based Science Classroom

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Abstract

The Supportive Multi-user Interactive Learning Environment (SMILE) software provides scaffolding to help students reflect on their experiences, describe them coherently, and articulate what they have learned. Currently used in middle-school science classrooms in the context of Learning by Design™ (LBD), SMILE aids transfer by supporting reflection and helping learners use case-based reasoning to its full advantage in a variety of ways.

Introduction

In this paper, we hope to provide insight on how SMILE (Supportive Multi-user Interactive Learning Environment) is used to promote transfer in a design-based science classroom. Because SMILE was created in the context of Learning By Design™ (LBD), we begin by presenting an overview of LBD. Then, we provide a general overview of SMILE and describe each part. We begin with the previously developed components and move into our most recent work and how each promotes transfer. In conclusion, we present ideas for future direction.

Learning by Design™

Learning by Design (Kolodner et al., 1998; Hmelo et al., 2000) is an approach to project-based learning (Barron et. al., 1998; Blumenfeld et. al., 1991). It is designed to engage students in science by helping them make connections between science and their lives. Pulling from project-based and problem-based approaches, LBD gives students opportunities to address their conceptions and misconceptions about science topics through hands-on activities.

In LBD, students learn in the context of achieving design challenges. These challenges provide a venue for identifying what needs to be learned, learning those things with an intent in mind, trying out conceptions, and refining them through iteration. For example, students learn about forces and motion from *Vehicles in Motion,* where they design and build small vehicle and its propulsion system that can navigate several small hills and continue to go beyond. They also learn how to design and run experiments, justify decisions using evidence, and communicate so others can understand.

The students generally go through several phases to address any given challenge. First, the challenge is proposed, the class discusses it, and the students "mess about" with materials to identify what needs to be learned before progress can be made. Then, the students divide up into groups to investigate, each choosing a different learning issue that the class identified. They report the results of their investigations to the class. After investigation, student groups apply their new knowledge to their first pass at a design to solve the challenge. Then, they build, test,

and share information as they iterate towards a working solution, discovering additional things they need to learn and reading and applying appropriate science concepts along the way. There is room for making mistakes, and little failures throughout the process provide a venue for confronting misconceptions and refining ideas. Learners are provided many opportunities for reflecting – on what to do next, on the procedures and practices used, and on understanding and use of the science.

Figure 1
The Learning by Design Cycle
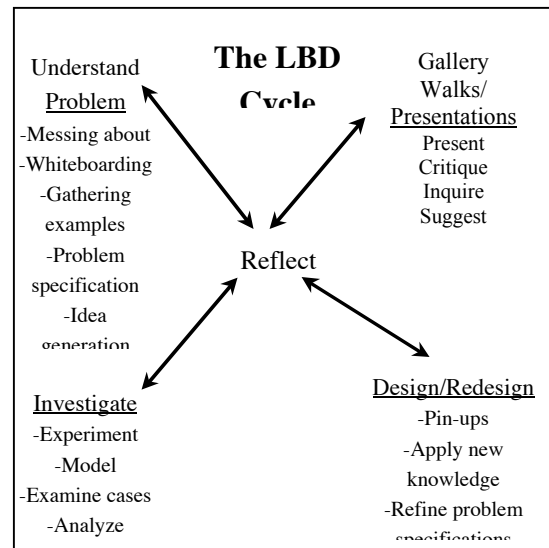
LBD's theoretical foundations are in case-based reasoning (Kolodner, 1993, 1997; Schank, 1982, 1999; Hammond, 1989), which suggests that one can learn deeply and in a way that promotes transfer by keeping track of one's experiences as indexed cases in memory, applying those cases in new situations, and seeking out explanations and refining one's knowledge if application of a case fails. CBR suggests reasoning that learners should do to interpret their experiences to extract key information and shows the importance of applying what one is learning in a way that will provide feedback and allow refinement over time. In particular, CBR tells us that important to turning one's experiences into accessible and reusable cases is

making connections between goals, plans, and what happened; connecting together the disparate parts of a design experience; extracting lessons that might be applicable elsewhere; and anticipating some of the situations in which those lessons might be useful.

Learning by Design's classroom practices are designed to provide the kinds of experiences and promote the kinds of interpretations of experiences that will promote transfer (Kolodner, Gray, & Fasse, submitted). Students report their findings, ideas, and experiences to their peers on a regular basis – identifying rules of thumb that can be derived from their data, justifying the decisions they've made based on data collected, explaining why things happened the way they did, and recognizing and asking for help with explanations that are difficult. Preparation for presentations requires students to do the kinds of interpretation of their experiences that case-based reasoning suggests are important for transfer.

SMILE Overview

SMILE (Supportive Multi-user Interactive Learning Environment) was designed to promote the kinds of reflection that case-based reasoning suggests are needed to learn from experience (Kolodner & Nagel, 1999). It is a suite of tools including the Design Discussion Area (to support planning investigations and presenting investigative results, design plans, and design experiences), the Case Authoring Tool (for guiding interpretation of expert cases), and the StoryBoard Author (for summarizing over an extended project experience and extracting lessons that can be learned from it). In current research, we are extending it to provide more complete support for LBD and other approaches to project-based learning.

Each of SMILE's modules is designed to help students focus as they reflect on their design, planning, or investigative experiences to get ready for a presentation to their classmates. The system helps them organize their thoughts and provides prompting in the form of hints and examples to help them make their presentations technical and complete. Case-based reasoning informs on the content of that scaffolding – the structuring and prompts we provide are those needed to make connections between their goals, plans, and what happened, to connect together the disparate parts of their entire design experience, and to analyze their experiences so as to be able to index them as cases for future use. Students collaborate in groups as they use SMILE. Once they write up a presentation, they publish it for public access and comment, facilitating collaboration across groups and access by students to their peers' experiences as well as their own.

Design Discussion Area

The Design Discussion Area (DDA) is the most elaborate part of SMILE. It helps students write up their Experimental Results, design plans (Pin-Ups), and design experiences (Gallery Walks) (Kolodner & Nagel 1999), and it provides supports for sharing their write-ups with each other and commenting on them. The hope is that by doing such sharing, students will get a chance to think about the concepts they are learning across several different contexts. As well, students find it useful to browse a database of their peers' experiences and ideas as they are working on their own solutions.

Each section of the DDA has scaffolding to help students reflect and report on their experiences. The scaffolding helps students develop scientific arguments and participate in important science practices in addition to helping them report their findings.

Figure 2
Left Side of Screen: Group Presentation

In the experiment section, scaffolding helps learners plan and then write up their experimental design, discuss how they ran it, analyze the data, and report results. Investigations are done by small groups; they use DDA to compose a presentation of results; they report on their investigation to the class; and they publish it in the software. Everyone in the class is invited to make suggestions or ask questions, both during class and later in the software. Published reports are available to students across the several LBD classes in the school.

Scaffolding for participating in a pin-up session (Kolodner et al., 1998) – a ritualized show and tell where students report on their design plans – helps

students articulate their design ideas and make arguments supporting each one, using evidence collected to date by the group and their peers.   In preparing for a pin-up session, students read and use the results of experiments reported using DDA. As for reporting on experimental results, students use DDA to help them prepare for a presentation; report to the class; publish in the software; and carry on discussions about their plans both in class and on line.

In the Gallery Walk part of the DDA, student groups post the results of implementing their most recent design (Figure 2). Gallery walks provide an opportunity for students to extract from their experience what they were trying to accomplish, why they made their design that way, what happened when they tried it, and to explain what went wrong and what can be learned from it, if anything. The feedback from their peers that they get here helps them decide what to try for their next iteration (Figure 3).

Figure 3
Right Side of Screen: Feedback for Group
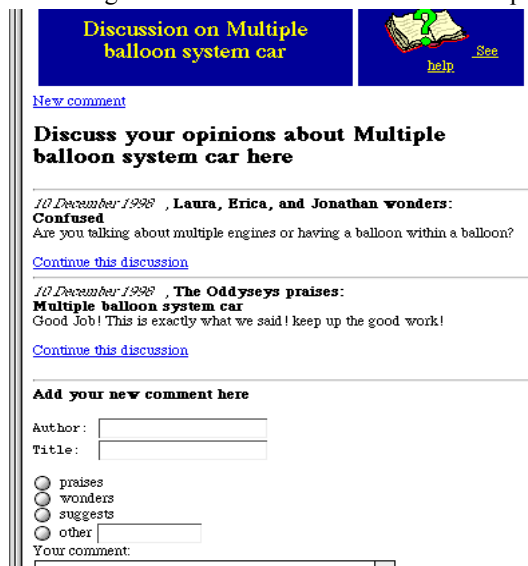
Other SMILE components

SMILE also has tools for helping students read and interpret expert cases and the beginnings of a tool for helping them summarize their whole project experience and extract what they've learned. Both are consistent with DDA – they provide structuring and prompting that help students put together good presentations and interpret their experiences well, and they allow for publication of write-ups and on-line discussion. Trials of SMILE show that its scaffolding indeed does what it was designed for when used as we've discussed above, but we also discovered several areas where SMILE is incomplete. We have recently started to move toward making it more complete, always keeping the design of its established components in mind.

The New SMILE Initiative

Recently, we've been working on adding to SMILE's capabilities based on what case-based reasoning and the transfer literature tell us is difficult cognitively and based on experiences we've had in LBD classrooms.   An important component of interpreting one's experiences, CBR tells us, is anticipating their future usefulness and indexing them in memory accordingly (indexing) (Kolodner, 1993; Schank, 1982, 1999).   The analogical reasoning literature, and our experiences in classrooms, show us that students need help transferring or applying what they see in peer and expert cases to their own challenge (Holyoak, & Thagard, 1996). There is a need, as well, for us to do a better job of helping students summarize over their full design experience. We see in our LBD classes that students gain a great qualitative understanding of the science they are learning, but that they can't learn the quantitative aspects of the science as well from design experiences. We are addressing all four of these issues.

Indexing

The first step in being able to transfer what's been learned in one situation to another is accessing or remembering an appropriate previous experience. In case-based reasoning, we call this the *indexing problem* (Kolodner, 1993). We learn that the indexing problem involves three important parts: labeling the case as it is entered in the library to allow for future use, organizing – and reorganizing – the cases to enable easy searching through the library, and actually retrieving the cases.

In the indexing system we are putting into SMILE, learners tackle all three of these parts of the indexing problem to some extent. We ask students to think about situations in which what they've learned from an experience might be useful and to index the case they've written up taking that into account. To do that, we provide two kinds of scaffolding: questions that get them thinking about what's important about the experience they've just reported on and organizing structure and key concepts to choose from for indexing. For example, when choosing indexes for experimental results they've just written up, we ask them to think about something that might stand out or a surprising result to help them anticipate how someone else might remember their experiment. Then we provide them with several menus of key concepts broken down into categories such as behavior they were investigating, physical attributes of what they were building that they varied, and science concepts their investigation illustrates. For each, they can choose from a variety of concepts to use as indexes. Some values for behavior while working on *Vehicles in Motion* are *distance traveled* and *trajectory*. One kind of propulsion system they investigate is a balloon-powered one; some

physical attributes they might vary for that type of propulsion system are *number of engines*, *size of balloons*, *length of straws*, *diameter of straws*, and *mass of vehicle*. Learners are encouraged to index their cases in several ways, and they can re-index their cases as their conceptions change.

We've begun by creating scaffolding and menus of key concepts for the kinds of write-ups students do with DDA – investigative experiences, design plans (pin-ups) and design experiences (gallery walks), but we plan to make it possible to index all artifacts written using SMILE's scaffolding, including interpreted cases, cases representing each group's summary of its project experience, and rules of thumb.

Case-based reasoning suggests that as knowledge is constructed by a reasoner, it is indexed in memory for future reference. The act of externalizing the indexing process reinforces the learner's mental index of cases (and adds it to the library for others to see) and, thus, promotes transfer. We hope that facilitating the indexing of cases will make it easier for students to find cases later, which will in turn make it easier to apply them.

Case Interpreting Tool – Supporting Application

We have found that although LBD has built in many affordances for transfer, that does not mean students can easily take advantage of them. Recognizing that an old experience or an expert case may be applicable, identifying which case to apply, and applying that case are skills that must be developed, and these skills do not come easily to most students (Owensby & Kolodner, submitted). Students find it easy to apply the surface level characteristics of a case to their challenge because the similarities between surface level characteristics of a source case and their challenge are usually a one to one match. However, identifying that a case is applicable based on causal structure is much more difficult. A source case may superficially seem unrelated to students' current problem, but the cause-effect relationships may show striking similarities.

We have observed several of our best LBD teachers to see how they help students overcome the difficulties they face when trying to apply cases. The most important thing we saw the teacher doing was helping students clarify their understanding of the source case and the challenge that they are currently working on.

One way of doing this is through helping students notice causality and sequencing. As stated previously, causal information seems to be the biggest obstacle for students to overcome when applying cases. So when the teacher asked, "What happens when you cut down trees?" to which a student replied, "When the trees were cut down, the dirt slid," that student identified a causal relationship that may not have been clear to him

had he not been prompted by the teacher. When students read aloud a case involving an incident in which a landslide destroyed a small town, and the teacher stopped them and asked, "What happened there?" one student replied, "It got hot, the snow melted and caused a landslide," thus answering the question by identifying the sequence of events and the causal relationship. Asking the students about their understandings of the source cases and the challenges along the way not only solidifies the student understanding, it helps students identify questions they should be asking themselves when they are reading for understanding.

Another way the teacher helped students clarify their understanding was to identify and break down difficult vocabulary. While reading the same landslide case, students came across the term "clear cutting". As soon as it was encountered, the teacher stopped and asked, "What does 'clear cutting' mean?" Clarifying difficult vocabulary can help clarify a case and heighten students' understanding of that case.

The teacher also helped students identify the role that certain artifacts or items played in a case they were reading about. Asking "What do trees do to the soil?" when reading the landslide case is intended not only to help students identify the role that trees play in preventing erosion, but also to serve as a reminder when students are engaging in stream table investigations later. The teacher's hope was that when water caused the dirt to slide down the incline in the stream table, they would remember the landslide case and the role of trees, and apply that solution to their model.

The teacher also exposed students to a variety of cases, in addition to the ones provided by LBD, that were related to one another and the challenge they are trying to solve. Exposure to and analysis of cases that are related to the class challenge both through surface level and causal relationships is meant to increase students' library of cases, help students identify applicable cases based on both characteristics, and help them develop the skill of identifying and applying cases in better ways. In *Digging In*, students learn about and obtain several related cases through reading about topics like landslides and the Dust Bowl, taking an erosion walk, and participating in other activities. In addition, students may also need to be explicitly reminded of cases.

In light of both the needs of students and the role of teachers in promoting successful transfer, we have developed the Case Interpreting Tool, which scaffolds the examination and application of expert cases to the challenge they are trying to solve. As students read the expert case, they are asked to focus on several aspects of the expert case and their challenge. One of these aspects is the sequencing of events. This gives

students the opportunity to explain what happened in the case in their own words, and it also helps students make sure that they understand everything that is going on in the expert case, including what caused certain events to take place.

Next, students are asked to justify whether or not the same thing could happen in their challenge. Students can then examine both superficial and cause/effect relationships and use events from the expert case and/or their challenge to support their claims. Then, students examine the solution that was applied in the expert case. In particular, they identify how the experts solved the problem, why that particular solution was applied, and what happened as a result of that application. If the solution used by the experts turned out to be a poor solution in one or many aspects, students are asked to explain not only why the solution was poor, but also what the experts may have overlooked and how they could have done better. By examining the solution applied, students will be able to understand how the pros and cons of a solution can affect the solution applied in a given case. They can understand how stepping back and examining what worked or didn't work can inform design decisions for solving their present challenge and other challenges in the future.

Finally, students are asked to identify parts of the solution that are applicable to their challenge. They are also asked to explain how the identified parts of the solution can be applied, and predict the results. This will help students understand how to identify parts of a solution that may work, apply that solution, and make an educated prediction about how well the proposed solution may work for them. All in all, our hope is that the students will have a better understanding of the expert case, their challenge, and the process of identifying what makes an old case applicable to a new one, as well as understanding the process of actually picking out the applicable parts and applying them.

Summarizing One's Project Experience and Extracting Lessons Learned – A New StoryBoard Author Called CAT

The Case Authoring Tool (CAT) facilitates the summary of the experience of addressing a design challenge or project-based scenario. CAT scaffolds telling the story of one's project experience or writing a product history. The core components of a summary include elaboration of the challenge or problem, important iterations of the design or solution, and the final design or solution, including with each, the science and other evidence that justifies decisions that were made and explanations of a product's behavior.

While students are working in groups to articulate their experiences, they are provided with resources for helping them to remember concrete things that they may have learned along the way, whether those things are about science and technology (e.g. Newton's Laws), strategies for doing science (e.g. controlling variables), or project practices (e.g. collaboration). They each jot down notes about what they've learned and later write a rich elaboration of the most important things they learned, including concrete articulation of what they learned, their experience of learning it, other examples illustrating what they learned, and future use scenarios. Such elaboration is aimed at helping learners make connections between their project experiences and what they learned from them, and anticipate the usefulness of what they've learned and when they might want to remember it, all important for promoting transfer.

One recent research issue in designing CAT's scaffolding has been how best to help students identify elements of importance within the learning experience, whether identifying iterations of importance to the learning process or identifying things they have learned that ought to be elaborated upon. When we've asked students to recount experiences that they felt were particularly important, we've found that affect seems to play a significant role in the construction of importance and the recall of learning experiences. Students seem particularly to find meaning in those experiences that made them the most proud, frustrated, surprised, or curious. We've investigated several different ways of incorporating affective scaffolding to aid in the identification of elements of importance within an experience.

The other current focus of research on CAT is exploring the interplay between reporting the overarching learning experience and elaborating upon salient issues. Both the context provided by immersing the student in concrete experiences and the focus provided by elaboration seem to be vitally important in the learning process. This context and focus also seem to be interweaved in rich learning environments, and we are interested in exploring the rhythms and relationships between the two.

Bridging the Gap Between Qualitative and Quantitative Understandings

In their current incarnations, LBD and SMILE encourage an understanding of the qualitative realms of science. For example, in the *Vehicles in Motion* module, students begin to understand that different surfaces have different frictional properties and that a car will either go farther or less far depending on the surface. They also gain a preliminary understanding of Newton's laws and forces acting upon systems. This sets up a basis of understanding. But students, unfortunately, do not always gain enough of a quantitative understanding of these forces. Currently, teachers take time to explain how the formulas are used

to make predictions of the outcomes of various experiments.

We are working on an extension to the LBD experience that adds physical simulations to the experiments in the classroom. Currently, this has passed the developmental stage and we are building a prototype. In the future, students will be able to create models of the devices they've designed and built in class, vary their parameters, and run simulations to see what happens. While behavior in the simulation will be like what they build in the classroom, they will be able to better investigate the effects of small changes, see quantities changing over time, measure or compute some quantities that are too hard to measure in the world, and explore what happens without the noise inherent in the real world. For example, during *Vehicles in Motion* they will model the cars they've designed and built and change parameters of the components of these vehicles. The software will run a simulation and display the results. Students will be able to measure instantaneous velocity and acceleration as well as a host of other results that are not easily measured in a classroom. Students will also be able to graph their results to gain a better understanding of the forces at work. They won't have to deal with balloon engines that lose their elasticity as they are used over and over again. The software will enable them to make quantitative predictions about their real-world experiments.

This goal cannot, however, be achieved in one step. We must design a process that bridges their understanding of the classroom with a new understanding of the simulation. For this, we propose a three-phase process. In the first phase, students will build a model similar to the model they built in the classroom. The computer will then add force-vectors to their model (which they have seen in class) and run the simulation. This phase should help the student to see a correlation between their real-world models and those on the computer. During the second phase, students will be able to manipulate the force vectors themselves and see the results on the simulation. In this environment, students are able to see the results of removing friction or gravity from the model. Once again, this is not possible in the real world and should help them gain a better understanding of some of the forces at work. We would like to see the students use these simulation results in their discussions and also use them in the next iteration of model design. In the third phase, students will see the values associated with the force vectors that they have been manipulating. Though they can add and remove forces, they will be unable to change the values of the vectors directly. Instead, they will change parameters of components of their model. This will allow students to start to gain an understanding between local changes in a system and their effect globally.

We hope that this extension will help bridge the gap between the qualitative understanding of science with the harder to comprehend quantitative understanding by encouraging connections between simulations with exact numerical values and more approximate data collected in the classroom.

Future Plans

In our re-implementation, we have been considering the idea of using SMILE in other design-based and project-based classroom settings. It was originally designed to support LBD, but it seems that the separation would not change the effectiveness of much of the scaffolding already provided. SMILE could be used to support other design-based or project-based curricula with only minor changes.

Summary

All of these tools provide scaffolding for transfer. SMILE provides three types of scaffolding: prompts to help with articulation, structure to help with process, and examples to guide learners. SMILE promotes reflection in three different ways. During the design process, learners are prompted to write about what they are doing. This sort of reflection reinforces the process and the content knowledge. At the end of a challenge sequence, learners reflect on what they have learned by writing about their experiences. Finally, SMILE promotes reflection through collaboration. When learners engage in group problem solving, there are two layers of reflection and articulation. First, learners must reflect on what they are learning in order to articulate to the small group what they contribute. The second layer is when the small group must present their work to the whole class. When they decide what to tell, they are reflecting. When they are asked questions about their work, they reflect on what they have done in order to describe it to the class. It is in this process of reflection that learners ingrain what they have learned into their minds. This reflection is just the sort of thing that promotes transfer.

Contact Information

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