Drill Dissection
Formative In-Depth Assessment Report

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This document presents initial findings from a Video Interaction Analysis of Professor Sheri Sheppard's Drill Dissection activity in the ME99 course at Stanford. The goals of this document are to: (a) help improve the dissection activity and (b) to contribute to an overall evaluation of the activity for the Synthesis Coalition. We have prepared a video tape of short scenes from the class activity which illustrates our findings.

The Drill Dissection Activity
In this activity, students take apart a drill. Their main goal is to understand four areas of the drill's functionality. They select these areas from a longer list of candidate functions. The drill is a light-weight, battery powered model with a chuck that accepts either a drill bit or a screwdriver attachment. The students worked in class in pairs or triads over the course of approximately an hour. They worked at tables, using a screwdriver, and writing with paper and pencil. One of the two groups we analyzed also had a Hypercard stack available. This stack provided textual explanations, animated schematic drawings, and cross-sectional drawings of parts of the drill.

Sources of Data, Issues, and Analysis
We gathered data in three ways. First, we observed the drill dissection class. Second, we interviewed the T.A.s about the class. We were also able to interview some of the students briefly as they worked on the exercise. Third, and most importantly, we videotaped two groups over the course of their classroom activity.

In conjunction with Professor Larry Leifer and Margot Brereton at Stanford, we previously developed a set of four primary issues for analysis:

- Does the activity engage students in learning?
- Does the activity encourage teamwork and communication?
- Does the activity provide opportunities to practice engineering in the ways suggested by Synthesis goals?
- Is the activity likely to retain students in an engineering degree program?

The method we used is Video Interaction Analysis. Briefly, our analysis involves detailed scrutiny of the actual learning events as recorded on video, set in the context of field notes and interviews.

Findings from Direct Observation
Our observations during class were consistent with our field observations on the toy dissection activity, presented in a previous report. To summarize:

- all students appear to be highly engaged and on-task
- students direct and monitor their own learning
- time allotted for the activity was much too short
- students worked in teams, but did not necessarily communicate well
- students worked on issues relevant to Synthesis goals, such as using professional terminology, connecting design to function, and relating engineering concepts to a familiar object.

The new element in this situation was the Hypercard stack, and therefore, we focussed field observations on its use. First, we noted that students spent most of their time with the physical drill, rather than the stack. Upon questioning students about this, they said that they preferred to figure it out for themselves. Students said did not like reading a lot of text, and prefered exploring the device.

Students suggested two uses for the stack:

1) Getting supplementary information, e.g. about electricity ("this class isn't really about that").
2) Appreciating the quality of the engineering drawings ("they're really sharp drawings; they're good examples of how we should draw").

In addition, observations suggested a third use for the stack - as a point of common reference in conversations. For example, students pointed to the computer sketches while talking about the chuck mechanism. The cross-sectional drawings appeared to make it easier for to identify parts of the chuck; as they talked they went back and forth between the physical drill and the cross-sectional drawing.

Compared to toy dissection activity, we observed less sketching by students; instead students referred to the existing sketches on the stack. One possible reason is that the Hypercard drawings are of better quality than students' drawings, are less idiosyncratic, and are already in a public space. In the video analysis we explore these issues in greater detail.

Findings from Video Analysis

We performed two kinds of video analysis. First, two researchers watched the videos from beginning to end, taking notes. Second, a diverse group of assessment experts discussed selected scenes from the beginning, middle, and end of each tape.

The report on our video analysis findings has three parts. First, we present overall findings about learning, teamwork, synthesis, and retention. Second, we compare students who used the stack with a group that did not. Third, we present some observations about the role of teaching assistants.

One introductory observation requires highlighting: Safety is potentially serious issue in the drill dissection task. We noted some students engaging in quite unsafe drilling practices. For example, the male loosened the chuck by holding it while running the motor in reverse. As he himself noted, this could rip his hand off. He also put much too much body weight downwards in the screwdriver situation. A group of female students was concerned about potential shock from touching what they thought might be an exposed capacitor. Students need some safety instructions before engaging in drill dissection. Also, a clear sense of safe and dangerous features will allow the most complete exploration of the device.

Overall Findings

Both groups we videotaped exhibited the positive characteristics we observed in the previous toy dissection activity. With respect to learning, we found that students were actively engaged throughout the time period. They posed challenging and relevant questions. Some were about terminology (e.g. "is that called a motor shaft?" or "you can't call that a pivot, can you?") and many were about conceptual issues (e.g. "I don't really know what torque is very much" or "what makes the motor get started going in the right direction?"). Others were about the functionality (e.g. "What makes the collar move with the drive shaft."). Students explored the device and the Hypercard stack to seek answers to their questions. We also noted that students were quite good at monitoring their progress on the assigned tasks, watching the available time, and keeping notes and records.

With respect to learning, time is a primary problem. Students have to rush through the task in order to complete their exploration of the drill in one hour. This encourages them to be satisfied with superficial answers to their questions. If time must be limited to one hour, we suggest that students focus on giving a thorough answer to only 1 or 2 questions.

Synthesis courses aim to develop teamwork skills, and this task provides ample opportunities for collaboration. We discussed teamwork issues extensively in our toy dissection report, and the same issues pertain here. While all students appear to work together, their collaboration is successful to different extents. Some students negotiate roles and work to integrate their accomplishments, while others simply fall into roles and make little effort to contribute to common knowledge. Some groups smoothly resolve conflicts, while others merely move away from trouble. One contrast we find useful is between "displaying knowledge" and "sharing knowledge." In a knowledge display situation, one student demonstrates to the others that he or she has knowledge, but does not necessarily work to integrate that knowledge into a shared understanding. We prefer situations in which students work to build a common understanding. Students will need more guidance to achieve this goal reliably.

Another concern is with the way the activity sheets tend to structure student roles within a group. The dissection activities are set up such that one student tends to fall into a "recorder" role. The recorder takes notes about the on-going activity in order to fulfill the task instructions. The problem we have observed repeatedly is that the students explorations often do not relate directly to completing the written assignment, and this can create a split between the recorder and the other group members. In particular, we have observed several situations in which the recorder withdraws from the group in order to continue fulfilling task instructions while the group continues to engage with the physical device.

A third area we considered was how the students' activity relates to Synthesis goals such as using professional terminology, connecting concepts to artifacts, relating analysis to design, etc. As in the toy dissection activity, evidence from the video tapes suggests that these goals are being admirably met within this experience. The episode below covers an extended conversation about torque that will illustrate the character of what goes on. Prior to this episode the students had used the drill both to drill a hole in a wooden block and to drive a screw into the block. In driving the screw, the students did not drill a pilot hole. Thus to put the screw in, the male student applied a significant portion of his body weight downwards on the drill to keep the screwdriver from sliding out of the slot. However, he still could not succeed in driving the screw in. Upon failure, he said "that's called torque; the drill has too much torque." In subsequent conversations, we observed some confusions between speed and torque. After this activity, as the students were preparing to follow the task instructions, the following conversation took place:

1 M: so I don't really know what torque is very much. It's kind of like...
2 F: I think its force times distance
3 M: yeah, but what it comes down to in English. Like does this stop at a certain point rather than keep going? You know what I mean? Like less torque means when you are screwing in and it hits the end? Then it will stop rather than just demolish the screw.
4 F: I thought torque was just the amount of power it has to apply force.
5 M: It's the amount of power its given, yeah. If its giving it too much power, sometimes you don't want to do that.
6 F: So you're like talking about variable force
7 M: Yeah lots of them have variable force
8 F: Does this one have variable force?
9 M: Cause if your like screwing in the screw, you don't want to give it as much power or else its going to just demolish the screw.
10 F: OK.
11 M: Whereas if you are drilling you want it to have a lot more power, you know what I mean? Like did you notice how when we were drilling it drills really slowly, but when we are screwing, it screws far too fast?
12 F: mm, hmm
13 M: like its not just a speed thing, it's a torque thing.
14 F: so this doesn't have (continues but hard to hear)
15 M: it doesn't have an adjustment, it has an in-between one, it has one that is in-between, you know what I mean?

This conversation is an excellent example of the need for the Synthesis project. In the first line, M poses an important question: "what does torque mean?" F responds with the textbook definition, which is not immediately useful in this context (as Margot Brereton points out, it is easier to think of torque as "turning force" than "force times distance" in this setting). In line 3, M articulates the crux of the situation: the students need to understand how the concept of torque applies to this particular situation. As the conversation proceeds, it becomes clear that the students have not yet completely sorted out the meaning of torque among a series of related terms including force, power, and speed. Design issues also emerge: this drill does not appear to be able to vary its torque, and may have implement a compromise which is not particularly good for either drilling holes or driving screws. To summarize, we observe that drill dissection provides strong opportunities for concept learning and design questions in a rich context of use.

This episode also shows the potential and the limits of self-directed learning in dissection tasks. Students quickly become deeply engaged in drill dissection and begin posing relevant questions. However, students may not have sufficient resources to critique and improve their own understandings. In particular, it is very hard for students to judge the quality of their own explanations. For example, in line 4 and 5, M and F are not aware that they need to distinguish power and torque. In line 6 through 8 they slip into talking about force. Line 11 doesn't describe the situation accurately: it doesn't screw too fast, but rather the coupling between the screw and driver can only sustain a certain amount of torque. When the required torque to turn the screw exceeds this, the screwdriver slips out of the slot and only then begins to turn very fast. In order to overcome this situation, the students don't need a slower drill; they need to reduce the required torque by drilling a pilot hole. Here there is a potential confusion between speed and torque; gearing down often increases torque while reducing speed, however low speed does not always equate with more torque. In particular, if the drill achieves low speed by delivering less energy to the motor, then low speed will probably have lower torque. At the end of the conversation, it is not clear whether or not the students have resolved the differences among torque, speed, force, and power concepts. The topic never returns in later conversations. Thus while the activity created a great opportunity for learning, it is not clear how much students learned.

In order to resolve the question about torque, and similar questions, these students need more guidance in making distinctions among concepts, carefully describing what occurs in the situation, and applying concepts systematically. In the absence of help in critiquing and improving their understandings, students are likely to produce fairly superficial and inconsistent explanations. Dissection activities should provide more feedback to students about the quality of their explanations.

We observed problems in critiquing and improving explanations throughout the videotapes. For example, in understanding how the motor starts turning in the right direction, M proposes a weak explanation that relies on the rotor already being slightly advanced in the desired direction. Also there seems to be a tendency for students to produce explanations that sound authoritative but are actually quite flawed. In this case more extensive inquiry may be blocked.

A final set of issues explored in these videotapes regards the potential to retain more students in engineering degree programs. Such long term goals are very hard to measure in short term observations, such as VIA analysis. Nonetheless, we have identified a few factors that are relevant: students should enjoy the activity, be able to succeed, experience freedom to express their thoughts and personality, and receive appropriate support when they need it.

>From the videotapes, it appears that students do enjoy drill dissection and experience freedom to express their thoughts, even if they are uncertain or don't know an answer. However, we noted that female students are somewhat less comfortable handling the drill than they were handling the wind-up toy. They may have less experience. A short hands-on lesson about using the drill might make students more comfortable, and could also address safety issues.

Receiving appropriate support was a significant problem for the group of three females. As we discuss in the section about the role of the teaching assistant, we are concerned that the students may have received inappropriate support from the T.A. If this happens commonly, it could have a negative impact on retention.

Findings about the Hypercard Stack

Our two videotapes include one group with the Hypercard stack and one group without the stack. An important general observation is that the no-stack group appeared to learn more and collaborate better than the stack group. Thus while the stack may have a positive or negative effect on students' learning, other factors (e.g. learning, teamwork, activity design, curriculum design) are probably more important than the mere presence of multimedia materials. For example, the character of the students teamwork appears to be more important than the presence or absense of multimedia materials.

Thus an interesting evaluation question is: what use did students make of the software? We observed four kinds of uses of the Hypercard stack. One relatively common use of the stack was simply to explore or browse its contents. This is not surprising because students were not yet familiar with this medium. We did note that browsing the stack could provoke some questions that might not be provoked by physically taking the drill apart. For example, the wiring schematic in the stack showed connections to ground, which provoked the question about how the circuits in the drill are grounded (they aren't). A second kind of use was to look for a specific piece of information in the stack. For example, students at one point used the stack to find out how a switch was wired. Here the stack could provide information that is hard to determine from the real device, with potentially messy and hidden wiring.

The third and fourth kinds of uses we observed are perhaps less obvious. The third use involved going to the stack as a source of "authoritative explanations." This occurred much in the same way that students might look for the right answer in a textbook. This is potentially worrisome because it detracts from the overall design of the dissection activity, which focuses on students figuring things out for themselves, on their own terms. Finally, we observed an important "non-informational" use of the stack, as a common point of reference for discussions. Students extensively referred to the high quality schematic and half-sectional drawings in their conversations. We believe this is because it is much easier to point to a specific component in a half-section drawing than in the actual drill.

In relation these uses of the stack, we observed several problems. As we mentioned earlier, there is not enough time to do the dissection task. It also takes time for students to figure out how to use the stack. Thus they spend time exploring the stack, rather than learning from it. This phenomena, of course, could diminish as such stacks become a more common part of the students' experience. A more significant problem is the stack can force divided attention among the collaborating team; it is difficult to coordinate activity with the drill with activity with the stack. When there is only one device, students are encouraged to jointly focus attention on it. In contrast, we noted that the two members of the team we observed often worked separately on the stack and drill. Most importantly, they did not often coordinate information between two objects.

Our evaluation group suggested that this may be a generic and fairly deep problem; coordinating two distinct sources of information within a collaborative team requires specific work practices. The students we observed seemed to focus either primarily on the stack, or primarily on the drill, but did not relate knowledge gained in one context to the other. In addition, we noted that the more abstract representations that appear in the stack require interpretation, and students often do not know the correct interpretations. For example, students who are not familiar with electricity cannot read a electrical schematic. Thus rather while it can provide information, the stack can also be a source of additional confusions.

In addition to considering how students used the stack, we also examined the videotapes to see what sorts of information students appear to need. The issue of safety and usage instructions was quite important in both groups. A set of QuickTime movies might be able to quickly instruct students in appropriate use of the drill. Also students often had questions about terminology, which could be answered by providing a set of labelled drawings. A couple of other needs, however, cannot be met through the stack. In particular, students need help critiquing and improving their explanations. We believe that "cast in stone" textual explanations cannot serve this purpose without detracting from the overall activity, and therefore this help should be provided by a teaching assistant, rather than by the stack.

Findings about the Role of Teaching Assistants

The video-tape analysis has presented a number of issues regarding the role of the teaching assistants in the dissection activities. First, we observe (from one of the tapes) that when the T.A.s intervene, it is not necessarily to the benefit of the students. For example, in one case, three students ask a T.A. a specific question about a component's name and the T.A. does not answer the question; instead, he takes up his own line of questioning about such things as the shape of bearings and the manufacturing process. The effect this has on the group is striking. What previously was a coordinated and engaged team effort breaks down as two of the participants pull back and become silent while one of the group members converses with the T.A. This example suggests two points about the T.A.s role in these activities. First, because the T.A. is not monitoring the on-going progress of the students, he (or she) cannot know know how much and what kind of explanation to give so that student work can continue to flow smoothly. Second, since this type of monitoring seems improbable (with the T.A.s time distributed among many groups), the T.A.s instead need to especially responsive to the questions that students ask. The issue is not simply resolved however by instructing the T.A. to answer only the questions asked; certain situations (observed in other dissection tapes) suggest that sometimes T.A.s use questions as occasions to profitably "teach" on a extended topic.

A second concern was the character of some of the T.A. explanations; these tended to closely resemble what is found in text books and bore little on the experience at hand. For example, in response to a question about how the drill's motor works, a T.A. tells a student, "you know what an inductive field is... it's basic electromagnetism... look it up it's not difficult." Not only is the explanation unclear, but it seems antithetical to the spirit of the dissection exercises. One hypothesis about why a T.A. would give such an explanation is that dissection exercises are just as unfamiliar to the T.A.s as they are to sophomores. As such, they are likely to give explanations that are familiar from their own curricular experiences, that is, more formal, less grounded descriptions of the phenomena at issue.

Recommendations

Our recommendations extend and further specify those presented in the Toy Dissection VIA report. In that report, we suggested:

- experimenting with longer time blocks
- consider using a less complex device
- experimenting with task instructions
- exploring more teacher involvement.
- exploring additional information resources

Time and the complexity of the task are still problematic in drill dissection: students either need more time or fewer questions to answer, so they can explore the questions in more depth.

With respect to task instructions, the major issue is how the instructions lead the students to adopt particular roles in their teams. There is presently a problem in which one student becomes the "recorder" and tends to participate less in exploring and explaining the device. Also the activity focuses on producing written explanations, and the students do not receive constructive criticism on their explanations. One alternative that might remedy both problems would be to have students present orally after the dissection exercises. This would allow each student to participate fully in exploring the device during the dissection and in producing the explanation at the end. Students might also be asked to discuss how their group worked together as a team, providing an opportunity to address collaboration issues. Students could receive some constructive criticism, and the instructor would gain a sense of what students had learned. To the extent that the task still requires written work, students might be asked to rotate the role of recorder within the group.

With respect to teacher involvement, our findings suggest that students need help particularly with critiquing and improving their explanations. Presently, teaching assistants do not tune in to the issues that a team is grappling with. Likewise, students are not aware that they should use the T.A.s to get feedback on the quality of their explanations. Teaching assistants need to develop more sensitivity to the students' need for feedback on the quality of the explanations, and to the kind of answers that are likely to satisfy student questions. We also think that students could use some explicit coaching about their collaboration. One way to build these sensitivities would be have the T.A.s watch some of the dissection video tapes, and discuss and critique their performance. We also thought that T.A.s might not be familiar enough with the purpose and methods of dissection activities and the degree of change this requires in how they interact with students. It might help to provide more explicit training to T.A.s about their intended role.

Finally, our evaluation group suggested that the Hypercard stack focus on two areas: providing drawings and schematics that support students conversation and extending students' dissection experience through simulation. Computer software could allow students to explore simulations of a variety of types of drills that are not ready at hand. For example, we noted that students had trouble distinguishing torque from speed and power. A computer could simulate the torque-rpm curves of a variety of different kinds of motors, thus giving students the opportunity to explore the space of possibilities. There could be less emphasis on providing correct information and more on providing simulated experiences that complement the hands-on experiences students have with the drill. To summarize, we see a distinction between two possible roles for the stack: "informational enrichment" versus "conversation-activity support." While our sample is quite limited, it suggests that the information-providing uses may turn out to be problematic, and it may be best to focus on supporting students conversations and activities. Thus the most useful stack might provide high quality drawings that enable students to converse more precisely and simulations that enable students to generalize beyond the specific drill that they use.