LEARNING THROUGH A COMMUNITY OF PRACTICE APPROACH

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Without argument, discipline expertise (or competency) involves developing skills in the use of specific tools of the trade and practices of the field. What is not as evident is that these very tools and practices help to shape students' knowledge and thinking in a discipline. This knowledge and thinking includes understanding of rules, methods, as well a philosophical assumptions and ways of knowing. These might be considered *epistemic frames* of a discipline (Shaffer, 2004).

One way of thinking about this knowledge is to picture it as a type of "meta-knowledge" or "meta-competency" that is gained through the use of tools and practices. It is the "stuff" that is often taken-for-granted by experts in the field because it is embedded in the very interactions between them and their tools (Cobb, 2002).

Consideration of the acquisition and role of this meta-knowledge in discipline competency raises interesting questions for the design of instruction, particularly at the college level, because teachers are experts in specific disciplines. As a consequence we might ask how providing students with opportunities to use tools and engage in practices promotes the construction of this meta-knowledge.

How might we design instruction to achieve these ends? And what other learning implications are there of focusing attention on the tools and practices of a discipline?

In this paper I attempt to answer these questions by looking at a case study of students using an instructional program designed to feature the use of particular tools and practices of science – *i.e.*, using models as a tool of science and the scientific method as a fundamental practice of science. Although this case study looks at the issues through the lens of a particular science domain, the ideas expressed are intended for a general audience. The purpose is to spark a more global discussion about the role of meta-knowledge in designing instruction for competency-based learning. In the following pages, first I provide a brief background of the literature and my rationale for the design of this instructional approach. Next I describe the study and present a sample of the results. And lastly, I propose some guidelines for the future design of college instruction.

BACKGROUND

John Dewey (1915), often considered to be the father of modern day educational philosophy, identified the close connection between knowing and doing. Nearly a hundred years later educational psychologists and scholars maintain the position that placing learning opportunities within the context of practice will promote better understanding and use of knowledge. Based on the socio-constructivist paradigm, this is called *situated learning* (Greeno, 1998). Within this perspective it is believed that the context and challenges to be faced influences what can be learned. To this end, Brown, Collins and Duguid (1987), in their seminal article on situated cognition, suggest that knowledge is not separate from where it is to be used and what it is to be used for. It is in fact "co-produced" by the situation and the activity. Situated learning also concerns itself with what I have called the "meta-knowledge" which is embedded in using tools in their intended context.

COMMUNITY PARTICIPATION AS AN IMPLICATION OF TOOL USE

Using discipline-specific tools and practices is not "value-free." That is, tools are used within a socio-cultural context of norms and values and each discipline has a common system of standards and criteria for evaluating processes and products. For instance, social scientists agree that research and its findings should be judged on the logic between the research design and how well that design can answer the research question, and on what will determine significant differences between the treatment conditions.

Brown, Collins and Duguid (1987), cited above, suggest that activity with tools is influenced by the community's practices:

> Because tools and the way they are used reflect the particular accumulated insights of communities, it is not possible to use a tool appropriately without understanding the community or culture in which it is used. (p.34)

Thus, familiarity with a discipline's tools and practices is likely to reveal one's level of disciplinary expertise or competency; and it may involve a sense of community membership.

Such are the fundamental ideas behind what Lave and Wenger (1991) consider to be participation in *communities of practice*. According to Wenger (1998), communities of practice are constituted when people come together because of shared concerns, problems, or a passion about a topic. The interactions of such groups produce a source of constantly expanding and cultural common knowledge and skills that we consider expertise.

Learning can be characterized as entering into this system of practice and moving toward the center, a process referred to as *legitimate peripheral participation* (Lave and Wenger 1991). Early activity with tools would be small in scope but authentic in use. From this perspective, we expect students (newcomers) to engage in meaningful activities of the discipline (community). For example, if we design instruction for science based on what we know about scientific investigations, we would design opportunities to work with models to develop, test or improve the understanding of said model. This said, I will provide a brief description of models and their role in science.

MODELS AS TOOLS OF THE DISCIPLINE

Models as tools mediate thinking and understanding. They are human constructs that allow us to describe, explain, and make predictions about phenomena that we believe exist because of observation or logical deduction (Grosslight *et al.*, 1991). Testing our models allows us to produce data which in turn are used to confirm, modify or change existing models, conceptual or otherwise. Models, as such, are ubiquitous in academic fields. However, scientific models hold a privileged status within their disciplines in that they often describe laws and principles that have withstood the rigor of time and testing. Practicing science means using models to describe, explain, and predict the behaviour, structure or function of phenomena or events.

But models are complex tools to use because they can be presented in a variety of forms or representations. They can be physical, pictorial, graphical, textual, analogical or mathematical representations – although mathematical forms are often given greater importance in science because of their completeness and elegance. Experts use multiple representations because each has a specific function and presents a new opportunity for mediating thinking. It is these representational differences that make using models challenging for students even though intuitively they seem to be a natural extension of our thinking with analogies (Gilbert, 2004).

Given that many of the physical, pictorial or graphical representational forms of scientific models are incomplete in and of themselves, it is necessary to use multiple representations to explain a single phenomenon. Helping students to move between such visual and verbal analogies is no simple matter. Such reasoning requires a display of "transfer," which is a sophisticated cognitive task and difficult to achieve (Bransford & Schwartz, (1998). As a consequence, most learners need cognitive support (a scaffold) to move between representations because of the varying degrees of cognitive stress involved with the transfer task. In the current study a cognitive scaffold was designed to help learners visualize the different representations of models used – from physical, to pictorial, to vector, to mathematical. I refer to it as a *bridging tool* (similar to a free body diagram). It was extremely useful in helping students apply the scientific model to their physical models.

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MEDIATING FACTORS TO CONSIDER

Before moving on to the details of the study, there is one more concern that we need to consider. Some Learning Sciences researchers suggest that there is a link between students' pre-existing ideas about knowledge and knowing (epistemic frames) and how these students choose to participate in inquiry-based instruction (Sandoval, 2003). However, the community of practice literature suggests that by participating, newcomers may come to share in a sense of membership.

The current research examines these claims and proposes some explanations to clarify the relationship.

This research was an ethnographic case study (Garfinkel, 1967) designed from data collected as part of a larger research project conducted in the physics department at Dawson College. Participants were volunteers recruited from two cohorts of introductory physics classes – honours science and preparatory science[1] – forming what could be considered to be micro-communities (hereafter referred to as *m-communities*). In total there were sixteen students split across these two m-communities, (10 honours and 6 preparatory). Though the distribution seems somewhat uneven, these numbers represent proportionally similar participation from their respective populations, *i.e.*, the honours and preparatory classes. Sessions were scheduled in such a way as to enable the m-communities to meet separately.

THE INSTRUCTIONAL PROGRAM

The instructional program was based on the approach to learning called *Learning by Design* (LBD) (Kolodner *et al.*, 2003). It is a project-based program that uses design and scientific inquiry methods to promote the practice of scientific investigation. In the course of engaging in the program's activities, students learn to run scientifically controlled experiments, to collect and interpret data and to make further decisions based on results which can be explained scientifically. In short, they use authentic scientific practices and scientific argumentation to make their decisions. Additionally, the iterative approach to learning activities provides multiple opportunities to practice and improve their skills and competency in model-building and in developing scientific ways of thinking.

To further promote the development of robust conceptual knowledge, computer simulation software called SIMCARS was adapted for this study (Vattam & Kolodner, 2006). It provides students with the opportunity to apply the same set of variables that are part of the program's experiments to different representations of a model.

> *[...] placing learning opportunities within the context of practice will promote better understanding and use of knowledge. Based on the socio-constructivist paradigm, this is called* situated learning.

PROCEDURE

The instructional program consisted of six 60-90 minute design activity sessions held weekly for six consecutive weeks. In the introductory session an overview of scientific practices was presented with the emphasis on describing the role of models in science. In sessions two to four, groups of 3-4 students worked on designing and testing physical models with the aim of collecting data and explaining the physics of the model. An important feature of the instructional approach had each group working on unique aspects of the model's design. This way, each group's contribution was important to the collective knowledge of the m-community. Session five consisted of group activities using SIMCARS, a computer model. In session six the groups designed a pencil and paper model within specified constraints. And at the end of each session, the groups shared their results and thoughts with members of their m-communities.

The participants were videotaped and members of the research team took field notes of the sessions. The groups were asked to report their findings in writing and these were collected along with other artefacts. Questionnaires relating to understanding the role of models in science (*i.e.*, epistemic belief about models questionnaires) were distributed to individual participants before and after the instructional program (see final PAREA report). And finally, participants were interviewed after the completion of the instruction using questions that elaborated on the above questionnaire.

RESULTS

CASE STUDY ANALYSIS

The videotaped data were transcribed and analyzed using discourse analysis techniques. These analyses provide a glimpse of how students' participation in the design and testing activities co-evolved along with their ability to understand how to apply the rigors of the scientific method. These analyses also reveal how students used the physical models, computer model (SIMCARS) and the bridging tool (the designed cognitive scaffold) to begin thinking about the larger issue of the use of scientific models as a way of explaining phenomena rather than merely as arbitrary statements

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[1] There are three science programs at Dawson College: Honors, Regular and Preparatory. In the **Honors** program, students are required to have an average grade of at least 80% in Secondary V (final year of high school) and 80% in each of their Secondary V math and science courses – Math 536 (Functions), Physics 534 and Chemistry 534. In the **Regular** program, students are required to have an average grade of at least 70% in Secondary V as well as in their math and science courses – same as above. And in the **Preparatory** program, students had grades less than 70% in their math and science courses, or they had not taken one or more of the required math or science courses in high school.

of fact. In this short paper I cannot do justice to the data that demonstrate all these developmental trajectories. For present purposes I will focus briefly on one aspect of the ethnographic data from the perspective of the two m-communities. For those who are interested in reading more about the results of the questionnaire and interviews I direct you to the full research report for the funding agency PAREA (Charles, d'Apollonia, & Simpson, 2007).

BUILDING PHYSICAL MODELS AND USING THE BRIDGING TOOLS

The Honours m-community case.

Students in the Honours m-community had an advantage when it came to their ability to quickly engage in all the instructional program activities of using models. Their ability to quickly understand the larger learning objectives allowed them to move swiftly through the challenge of designing scientific experiments using physical models. Facility with these physical tools meant that they had time to engage in refining their practice of science – that is, the data collection. Later, this ability to produce cleaner data, coupled with their richer knowledge of content gave them another advantage. These honours students recognized more quickly how and when to link the results from their physical models in order to support the principles that make up the scientific model (in this case Newton's laws). The bridging tools were instrumental in this regard. Take for example the following excerpt from one group's discussion. (N.B. Pseudonyms are used for all students).

01 Nazir: Kinetic friction is the, what is it, the friction that resists a moving object.
02 Frank: OK, so the object's in motion, it experiences kinetic friction if it's on a surface because the object is moving. (Gestures: one hand palm up, the other moving back and forth above it.)
03 Tarun: So what's static friction?
04 Frank: It's when it stays still.
05 Tarun: Yeah, so what's opposing it? Getting in, into motion? Like…
06 Nazir: The molecules of, what is it, the car and the ground are too, are somehow… (Gestures: tapping the fingertips of one hand against the fingertips of the other hand.)
07 Tarun: Bonding.
08 Frank: And that's where mu (gestures quotes) comes in, right? You have to overcome that mu. (Moves toward the table and slides back of hand against it.) Like the table is probably greater than the floor. (Scuffing his foot on the floor and saying something inaudible.)

Ethnographic observations show that in the early sessions, even with these advantages, the Honours m-community also struggled to control the multiple sources of error in their design. Furthermore, they required multiple opportunities for practicing their data collection to discover and control the major factors linked to the quality of the data.

the preparatory m-community case

As expected, students in the Preparatory m-community had a more difficult time understanding the learning objectives of the design activity and therefore a more difficult time engaging in using the tools and practices of the discipline. Instead they initially focused on the physical model design challenge itself.

> *[…] the differential developments among students […] meant that some participants stayed at the edge of the community of practice, while others moved inward.*

However, with repeated opportunities to engage in the practice of designing experiments, they too began to recognize the importance of controlling error and eventually began to work toward those ends. When it came to using the bridging tool, their uses were limited to simple elaborations of science. But this was probably the first time that these students had actually talked science.

01 Batuk: No, the arrow is in that direction (reaches over pointing at cell on storyboard).
02 Malini: An arrow in that direction (pointing).
03 Francesca: No it's this one, this side.
04 Malini: Yeah, (nods), but it's going up (pointing).
05 Batuk: But there is, but then again... (turning to Researcher 2) Are we counting friction here?
06 Malini: Yeah, for sure.

Most notable with this m-community are the differential developments among students. This unequal social development meant that some participants stayed at the edge of the community of practice, while others moved inward. Consequently, the practice of using the physical model to collect data continued to be "sloppy" while their conversations showed signs of an increased willingness to attend to details. The messiness of the data affected the ability of this

group to match their data to the scientific principles, thereby adding insult to injury.

DISCUSSION

Overall, the results of the discourse analysis and content analysis of the questionnaire responses and interviews suggest that experimental instruction, with its focus on practices and tools of science, can help to promote a certain meta-competency, as defined in this study. To examine this more closely, I classify the observed changes into three disctinct areas:

1. **understanding the purpose and use of a discipline's tools**
   – *i.e.*, scientific models and their purpose (and, in the process, developing an epistemology of models);
2. **understanding a discipline's practices**
   – *i.e.*, how to design and run experiments (and, in the process, developing ways of thinking in science); and,
3. **developing membership in a community of practice.**

Understanding the purpose and use of a discipline's tools.

Students in this case study showed an improvement in their understanding that the discipline-specific tool in use (*i.e.*, the use of models) was a form of knowledge. Though this development was different for the two cohorts, both showed change toward an accepted standard. What is important thing is that the Preparatory m-community required more time and more representations (Even though I do not show this, the SIMCARS model was particularly useful for them). These results support the common thinking that the Preparatory m-community benefits more from the use of multiple representations.

Understanding the practices of a discipline.

Overall, the instruction allowed all the students to participate in the practices of science (*i.e.*, the practices of designing and running experiments). Interestingly, both m-communities started off with a weak understanding of how to design open-ended experiments. The Honours students, however, needed only one session before they could begin to control many of the variables that caused error in their experiments and they became better at doing so with each practice session. In addition, by the third session they also began to understand the importance of the data they were collecting and began to use their data to make corrections in their experimental design thereby improving their epistemology of science – *i.e.*, using the scientific method for decision-making.

The Preparatory m-community did not understand the purpose of the exercises, and therefore they took more time to understand how to design their experiments and to control for error. This is a common problem for students using authentic design-based activities (Leonard & Derry, 2006). Therefore, educators and curriculum designers must ensure that learners are clear on the goals of their experiments and the epistemology of science.

Developing membership in communities of practice.

As a group, the Preparatory m-community demonstrated the biggest shifts with regard to their sense of membership in the community of practice. At the beginning they were enthusiastic but content to view the challenges as too much for them. By the end of the six-session unit, they began to actively seek out opportunities to make sense of the tools they were using and the concepts they had learned in their physics class. I attribute these changes to students' feelings of contributing and being willing to take collective responsibility for the success of the activities. The confidence gained through repeated practice helped the Preparatory students act more like the Honours students, even though their conceptual knowledge remained weaker.

At first this finding seems contrary to the proposition that students' lower epistemic frames may hamper their inquiry activity, as mentioned earlier. However, when we look closely, the results reveal that in fact there is a co-evolution between the students' epistemic frames, as revealed in the questionnaire, and their willingness to participate. And the differential participation patterns we saw in the Preparatory group could be explained by similarly differential epistemic frames development among students when interviewed after instruction.

IMPLICATIONS FOR COLLEGE TEACHING

The results of this study have several implications for designing instruction for discipline competency. Here is my recommended list of guidelines:

1. Tools of the discipline need to be presented explicitly.
2. Whenever possible, multiple representations should be used, but they need to be linked together by scaffolds – *e.g.*, a bridging tool.
3. Bridging tools should be used in conjunction with collaborative activities. By doing so, conversation among students is encouraged.



4. Instruction should include repeated opportunities to use and iteratively improve students' understanding as well as to improve skills through practice.
5. Instruction should require students to share the results of their activities and to be responsible and accountable to themselves and their peers for the quality of these results. By doing so, students become engaged in their own learning and begin to feel that their contributions count.

CONCLUSION

In conclusion, defining "meta-competency" in terms of understanding the ways of thinking as well as the underlying meanings of tools and practices, particularly in communities of practice, is a productive way to improve competency learning. This study shows that, to some extent, instruction designed to accomplish such goals can be successful but it also holds challenges including above all the challenge of finding time. We therefore need to know if it is worth the trade-off? Does having meta-competency make it easier to learn other competencies? Do we need to rethink what we hold to be necessary competencies? Such questions are subjects for further study. ◖◗

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REFERENCES

BRANSFORD, J. D. & D. L. SCHWARTZ, "Rethinking Transfer", *Review of Research in Education*, Vol. 24, pp. 61-101, 1998.

BROWN, J. S., A. COLLINS & P. DUGID, "Situated Cognition and the Culture of Learning", *Educational Researcher*, Vol.18, Nº 1, pp. 32-42, 1989.

CHARLES, E. S., S. T. D'APOLLONIA & M. SIMPSON, "Promoting Conceptual Change in Physics Using Models", Technical report (ISBN number unknown at time of printing), for funding agency PAREA, co-ordinated through Dawson College, QC, 2007.

COBB, P., "Reasoning with Tools and Inscriptions", *The Journal of the Learning Sciences*, Vol. 11, Nos 2&3, pp. 187-215, 2002.

DEWEY, J., "The School and Society", Chicago, IL, University of Chicago Press, 1915.

GARFINKEL, H., *Studies in Ethnomethodology*, Englewood Cliffs, NJ, Prentice-Hall, 1967.

GILBERT, J. K., "Models and Modeling: Routes to more Authentic Science Education", *International Journal of Science and Mathematics Education*, Vol. 2, pp. 115-130, 2004.

GREENO, J. G., "The Situativity of Knowing, Learning, and Research", *American Psychologist*, Vol. 53, Nº 1, pp. 5-26, 1998.

GROSSLIGHT, L., C. UNGER, E. JAY & C. SMITH, "Understanding Models and their Use in Science: Conceptions of Middle and High School Students and Experts", *Journal of Research in Science Teaching*, Vol. 28, Nº 9, pp. 799-822, 1991.

KOLODNER, J. L., P. J. CAMP, D. CRISMOND, B. FASSE, J. GRAY, J. HOLBROOK, S. PUNTAMBEKAR & M. RYAN, "Problem-based Learning meets Case-based Reasoning in the Middle-school Science Classroom: Putting Learning by Design into Practice", *Journal of the Learning Sciences*, Vol.12, pp. 495-547, 2003.

LAVE, J. & E. WENGER, *Situated Learning: Legitimate Peripheral Participation*, Cambridge, Cambridge University Press, 1991.

LEONARD, M. J. & S. J. DERRY, *Tensions and Trade-offs in a "Design for Science" Classroom: The "Forces in Balloon" Lecture*, Proceedings of the International Conference of the Learning Sciences, Bloomington, IN, June, 2006.

SANDOVAL, W., *The inquiry paradox: Why doing Science doesn't Necessarily Change Ideas About Science*, Proceedings of the 6th International Computer-Based Learning in Science Conference, Nicosia, Cyprus, 2003.

SHAFFER, D., *Epistemic Frames and Islands of Expertise: Learning from Infusion Experiences*, Proceedings of the 6th International Conference of the Learning Sciences (ICLS), Santa Monica, CA, 2004.

VATTAM, S. & J. L. KOLODNER, *Design-based Science Learning: Important Challenges and how Technology can Make a Difference*, Proceedings of the 7th International Conference of the Learning Sciences, Bloomington, Indiana, 2006.

WENGER, E., *Communities of Practice: Learning, Meaning, and Identity*, Cambridge, UK, Cambridge University Press, 1998.

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