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Designing for technology enhanced activity to support learning

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Abstract

One of the perennial challenges in implementing and designing educational technologies is adapting to local contexts. Activity theory has the potential to address this challenge but has not seen widespread adoption due to its complexity. To address this, I suggest a simplified design heuristic for using activity theory to attend to contextual issues when implementing educational technologies. I then present two examples of this heuristic in use. First, I describe the BeeSign software, which was created to help early elementary students engage in complex systems thinking. Second, I describe the design of an online forum intended to foster authentic problem solving at the graduate level. Together, these examples illustrate the wide-ranging applicability of activity theory for designing and implementing educational technologies.

1. Introduction

A perennial challenge for both designers and implementers of educational technologies is how to adapt to local contexts. Classroom norms, organization, and resources all influence the effective adoption of technologies, but their infinite variety can make technology integration difficult. For this reason, sociocultural theories of learning like activity theory, which build on the work of Vygotsky (1978) and explicitly theorize the role of context in learning, have gained a great deal of attention in academic circles, including in the design of educational technologies (Kaptelinin & Nardi, 2006). However, despite increasing attention, these theories have not had the same impact on practice (Roth & Lee, 2007; Roth, Lee, & Hsu, 2009). A number of possible reasons for the underwhelming impact of sociocultural theory in practice have been suggested. I will briefly detail three common concerns before suggesting a design heuristic intended to make it straightforward to capitalize on the strengths of sociocultural theory for designing more effective educational technologies and instructional units.

One common concern is that, because it suggests that every contextual detail matters, activity theory quickly overwhelms practitioners who are unsure which details to attend to and in

what order (Witte & Haas, 2005). Another possible challenge that practitioners face is the idea of the “dialectic” which is often viewed as unintuitive and challenging to interpret (Roth et al., 2009). The dialectic refers to ideas that are fundamentally inseparable. For example, sociocultural theorists have suggested that there is a dialectical relationship between individuals and the collective (e.g., the group or culture; Roth & Lee, 2007). What this means is that we cannot understand an individual without also understanding the group in which they live and vice versa—to analyze any group, we must analyze the individuals who make it up. This is in contrast to other theoretical approaches, which suggest that it is possible to consider these items as separate “variables” instead of recognizing their inter-connected relationship. For individuals whose primary experience is with these other kinds of theories, engaging with the dialectic can be challenging.

Finally, it has been suggested that, all too often, sociocultural theory is taken up in a superficial and therefore ineffective manner. Most notable is the Zone of Proximal Development (ZPD) which is defined as the difference between what an individual can do on their own, and what they can do with the help of a more capable other

(Vygotsky, 1978). When Vygotsky introduced this notion, his goals were two-fold: 1) to suggest an alternative form of assessment that focuses on skills students are just beginning to learn instead of those they have already mastered; and 2) to suggest that the learning which occurs at the edge of an individual's competence is the kind of learning likely to lead to big developmental leaps. However, many American theorists have addressed this in a much more superficial manner by simply focusing on the common-sense idea that students can learn more when someone is helping them, thus making it challenging for practitioners to benefit from the richer ideas underlying the initial theory (Cazden, 1981; Chaiklin, 2003).

Three Principles of Sociocultural Theory

While activity theory includes a number of defining principles which might influence design (c.f., Wertsch, 1981), I have found the following three to be particularly valuable in informing my design efforts.

The first principle is the notion of appropriation, which Vygotsky (1978) originally referred to as internalization (John-Steiner & Mahn, 1996). All new knowledge, whether it consists of "facts" or "procedures", is encountered first in a social context. The individual then appropriates this knowledge, transforming that knowledge into a personally meaningful form that can be applied in the world. This notion of appropriation addresses a common misconception about activity theory, that the social context requires other people, and that the individual learner is neglected. Instead, appropriation emphasizes the importance of cultural norms in shaping individual knowledge and recognizes the way that individuals view new knowledge differently based on their prior experience. This principle is crucial for reminding us that each "tool" we introduce to students will be shaped by the context in which it is applied, suggesting that the more authentic the context, the more likely learners are to apply the new tool outside of the classroom context.

The second principle is that all behavior is goal directed (Wertsch, 1981). When describing a group of individuals in a classroom or workspace,

the group is organized around a shared goal called an object (Engeström, 1987, 1999). The goal an individual holds not only motivates them but shapes their perception of the situation. It is, in turn, shaped by the tools the individual brings to bear on the situation. From a design standpoint, then, we need to either account for an individual's existing goals or help them to develop new goals. In either case, we should be aware of how this goal may transform an individual's experience of classroom activities. For example, many of the students I work with are future teachers and have a shared goal of being better teachers when they graduate. This means that they are constantly looking for how theory might inform their teaching, and they often ignore any content that does not easily fit into that vision.

Finally, at the heart of sociocultural theory is the notion of mediation. A mediator "stands between" the individual and the goal they are pursuing, shaping their engagement with it (Cole & Engeström, 1993; Roth, 2007). Tools are the most obvious example because they shape how we engage with our tasks. Activity theorists further include the community of peers as mediators, as well as the rules and division of labor which shape how we engage with our peers (Engeström, 1987). There are two key ideas worth noting. First, the way that tools are commonly used needs to be learned and we should design with that in mind. Second, we need to be mindful of the relationship between multiple mediators. For instance, the way individuals use tools is influenced by their understanding of local rules, and the division of labor can influence how they engage with their peers. Figure 1 illustrates the relationship between mediators and the shared goal (the object) of activity that are used in the first example below. Note how all of the mediators are inter-related, each influencing the others.

A Simple Design Heuristic

Whether we are building new technologies or implementing them within a classroom context, addressing each of the above principles in order provides for a systematic consideration of the social context of learning. First, a designer should aim to

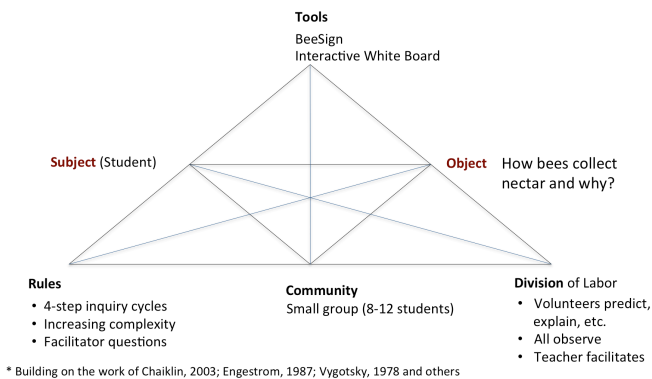


Figure 1: The Activity Triangle for BeeSign

support appropriation by specifying what individual learners will take away from the learning experience. The designer should note not only what students might be tested upon, but also on the social norms and awareness students should appropriate from the activity. The results of this step should guide all further design efforts. As with other theories of learning, a student's prior knowledge will shape their engagement with new content, and therefore what the student might appropriate in the classroom.

Next, the designer should consider any individual or shared goals that students may have for engaging in the activity. In some contexts, it is enough to simply build on students' existing goals. In others, it is valuable to help students develop new goals. The key issue to keep in mind is that the selected goal will shape an individual's perception of the situation, and therefore what they appropriate from the learning environment. For instance, we might leverage the goals of the pre-service teachers we saw earlier by helping them to see new ways to use class content in their careers. In contrast simply memorizing the textbook (a common student goal) likely ensures that the content will be irrelevant to the students and soon forgotten (Engeström, 1991).

Finally, the designer needs to select all of the key mediators. Witte and Haas (2005) have noted that this is challenging because there are so many possible mediators, and they might all be relevant! A simple solution is to first identify one or more "double-binds" (Engeström, 1987), or

situations where it is immediately obvious to students that their current knowledge will not help them resolve the problems they face. This motivates them to explore new tools or approaches. Seeking out an activity that promotes a double-bind allows the designer to identify the first mediator. Then, designers can iteratively define the rules, tools, and division of labor to support this activity. At this stage, it is valuable to keep in mind that there are multiple kinds of mediators in order to ensure that the social activity is designed around available tools, and to ensure built-in support for the chosen mediators (e.g., the tool should implement any desired rules, and potentially even make them more visible to the students).

The Approach in Action, Part 1: Teaching Elementary Students About Honeybees

My current research includes a number of research projects intended to teach early elementary students (k-3) about complex systems concepts in the context of honeybees collecting nectar (Danish, 2009; Danish, Pepler, Phelps, & Washington, 2011). As part of this curricular unit, I designed the BeeSign simulation software (<http://www.joshuadanish.com/beesign>), which helps students explore the system as a whole. According to the design heuristic listed above, the first step was to identify what I wanted the students to appropriate, or in other words, to select those skills I wanted students to learn. I identified a number of target concepts, but the primary focus for the software was to help students view, explain, and make predictions about how the hive as a whole responds to individual bee behaviors. Specifically, I wanted the students to recognize the efficiency of the bee "dance". Each forager bee does a "dance" to communicate the location of a viable nectar source to other bees, so that the other bees can then visit that source without having to first search for it. The software focused on this core concept in part because it was one of the skills not easily addressed through other existing approaches (e.g., having students learn the body parts of the bees by drawing them is something my partner teachers had done many times before).

With an appropriation goal now set, the next step was to identify a shared goal for the students' activity. In this example, the goal had already been defined: a better understanding of how bees collect nectar. I knew students this age would likely adopt this goal simply because they did not immediately have an answer when their teacher asked them how bees collected nectar. The challenge was in selecting the next step, because there are many ways to engage students in viewing bee behaviors, including existing tools such as NetLogo (c.f., Wilensky & Reisman, 2006). This is where the double-bind becomes quite useful. Prior research into systems thinking suggested that students would likely expect that the bee "dance" did not help the hive to collect nectar quickly, because it takes time away from individual bees searching directly for nectar. The software, then, is designed to support a comparison of nectar-collection techniques, allowing students to see the value of the dance (see Figure 2).

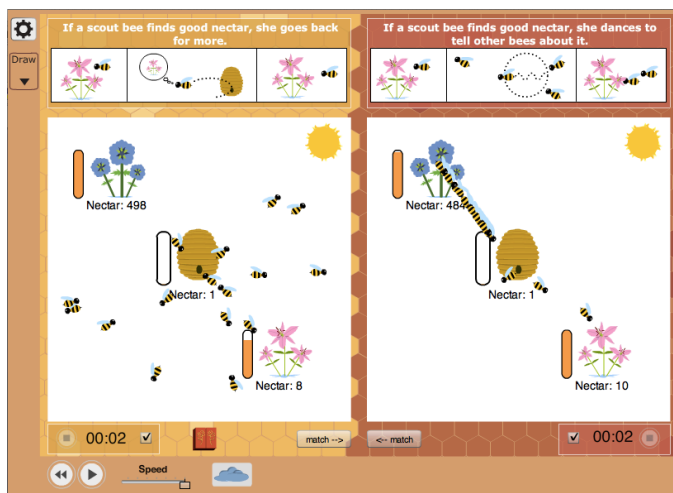


Figure 2: The BeeSign Interface

Many approaches to educational software design might stop here, employing good interface design principles to simply make this software effective at revealing this pattern. However, activity theory suggests that we must consider the other mediators of activity to better understand how this software will fit into the target classroom environment. Iteratively identifying these mediators required adjusting each component as needed (see

Figure 1 for the results). For example, it was clear that having the teacher involved in the discussion would help keep the young students engaged in cycles of inquiry to answer questions about the bees. Designing the software for use on an interactive whiteboard effectively supported this division of labor. Similarly, I embodied cycles of inquiry—rather than simply “showing” the result to the students—by providing a script for the teacher, and then making the software a full simulation that could be easily adjusted, rather than simply an animated video. The end result is a set of activities in which the teacher works with a small group of students to pursue several cycles of inquiry into the behaviors of honeybee hives using the BeeSign simulation software.

The iterative, cyclical consideration and reconsideration of mediators promoted a tight integration between the tool (the software) and the activity in which it would be embedded. The results have been quite promising and indicate that this design did support students as young as kindergarten in engaging with a number of complex systems concepts using the BeeSign software, despite the fact that many of these concepts prove challenging even for adults (Danish, 2009; Danish et al., 2011).

The Approach in Action, Part 2: Organizing Graduate Instruction With New Technologies

As the prior example indicates, activity theory was incredibly productive in designing a new software tool and accompanying classroom activities for elementary students. In the second example, we utilize the same principles to engage undergraduate and graduate level students in a meaningful way, and in a far more restricted environment in which the instructor cannot design and build new software from scratch (Danish, 2012): online discussion forums.

I recently had the opportunity of teaching two related courses at the same time, p540: Cognition and Learning, and p574: Computational Technologies in Educational Ecosystems. As the current design heuristic suggests, I began with one for each course: to help students develop a clear and common-sense notion of the topics being studied

that would support them in offering straightforward design suggestions to their colleagues. The p540 students were teachers who I hoped would apply their theories of learning to new course designs, and the p574 students were technology designers who would inevitably be asked to answer questions about how best to implement the technologies we were studying.

Cross-Class Forum Posts

In this case, the object of activity—being able to answer the questions suggested above—was something the students brought to the classroom themselves. However, I decided to further enhance this by making it authentic. To accomplish this, I created a shared online forum in which students from both courses were required to pose meaningful questions to the other class. The Cognition and Learning students asked their peers about how to implement technologies in their own classrooms. At the same time, the technology students, some of whom had not yet taken educational theory courses yet, asked their peers in p540 about how people learn. As the example indicates, the online forum was chosen as the tool for allowing students to ask and answer these questions. The remaining mediators quickly emerged in the form of the assignment, which required students to post their questions by a certain date, reply to multiple questioners, and to add something new to the conversation (i.e., they couldn't repeat what a prior student has said). See Figure 3 for an activity triangle describing this design.

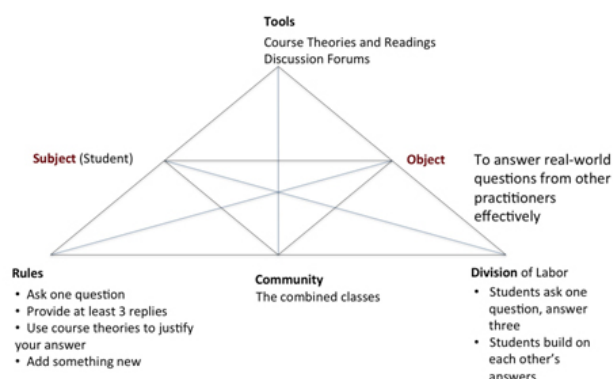


Figure 3: Organizing Cross-Class Forum Posts

The results were nothing short of astonishing. The simple mechanism of having students answer messy, real-world questions from their peers meant students addressed a wider range of problems, asked far more meaningful clarifying questions, and provided deeper, longer responses than I had seen in more traditional homework assignments. In short, the students genuinely wanted to provide meaningful assistance to their peers, and so they engaged in this real-world task with far more attention than students typically apply to artificial homework assignments. The students had adopted an object of providing useful theoretically grounded answers, rather than simply “satisfying the instructor.”

Conclusion

Despite the fact that activity theory is a robust and complex theory with hundreds of publications spanning decades, it has not yet lived up to its full potential of supporting the design and implementation of educational technologies for a range of messy, real-world contexts. However, it is possible to easily appropriate some simple principles and a design heuristic from activity theory that can support designers in reflecting upon the relationship between their designs, the students, and the environments in which they will interact. The goal of this paper was to briefly illustrate these heuristics in the hope that designers will be inspired to reflect more deeply on the goals of their students, and the multiple ways of mediating their engagement.

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