Designing for Dispositions

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Abstract: The purpose of this paper is to share the results of the first round of a design experiment, the purpose of which was to intentionally provoke in students particular ways of engaging with statistics. Specifically, in this study, we sought to design a curriculum which would support students' *procedural, conceptual*, and *critical* engagement with content, in order to develop *dispositions* towards engaging with statistics that involved: viewing representations as reflecting real phenomena; viewing operations and representations as tools that can be intentionally leveraged to develop and support particular arguments; and viewing justification and evidence as crucial components of convincing arguments. We present the design framework and rationale, findings and analysis from the first round of implementation. Implications for both design and learning are discussed.

Introduction

For the last 20 years, increasing numbers of researchers have demonstrated that what students learn cannot be separated from how they learn it (Boaler, 2000; J. S. Brown, Collins, & Duguid, 1989; Cobb, Stephan, McClain, & Gravemeijer, 2001; Greeno, 1991; Hutchins, 1995; Lave, 1988, 1997) and that knowing is an interaction among myriad components of complex systems. Rather than focusing on some amount of knowledge that an individual can acquire, this conceptualization of learning shifts attention to the kinds of practices that people participate in, and the ways people come to relate to each other within a particular activity setting. Learning is therefore considered to be a change in participation, through which one "becomes" a different person with respect to the practices of that activity setting (Lave & Wenger, 1991; Wenger, 1998; Wortham, 2004). This perspective suggests that renewed attention be paid to the nature of students' mathematical engagement—as inseparable from the specific content with which students engage—as a critical aspect of what students actually come to know and who they come to be. We focus on students' participation with particular content by investigating the development of *dispositions*; that is, ways of being in the world that involve ideas about, perspectives on, and engagement with information which can be seen both in moments of interaction and in more enduring patterns over time (Gresalfi & Cobb, 2006). Dispositions, unlike the word "predisposed," do not refer to innate or internal stable characteristics of individuals. Rather, dispositions capture *emergent continuities* (Gresalfi, submitted) in students' participation in a particular activity system. As Thomas & Brown, note, dispositions involve "attitudes or comportment toward the world, *generated through a set of practices* which can be seen to be interconnected in a general way…. Dispositions are not descriptions of events of practices, they are the underlying mechanisms that engender those events or practices" (italics added). In short, dispositions refer not only to what one knows but how she knows it; not the skills one has acquired, but how he leverages those skills.

It is clear that the dispositions that students develop towards a particular content area are built up through their experiences with that content (Gresalfi, Boaler, & Cobb, 2004; Kilpatrick, Swafford, & Findell, 2001; Lampert, 1990; Schoenfeld, 1988). However, less is known about how to deliberately foster particular dispositions towards learning. To make progress on this question, we conceptualize dispositions at three levels: engaging information in local events (taking up intentionally designed opportunities to learn in an activity or assignment); ways of approaching information in a particular subject area or setting (emergent continuities in the opportunities that are taken up); and ways of seeing and engaging the world across settings (lens or perspective on the world that impacts decisions about what to work on and how long to persist). By distinguishing between engagement in moments of interaction and dispositions across activities and settings, we are deliberately focusing at different timescales which are mutually reinforcing (Lemke, 2000); indeed, participation in moments of interaction can be considered to be evidence of, and reinforcing to, more enduring participation over time. This paper focuses on designing for students' *engagement* with content with an eye towards fostering emergent dispositions.

In this design experiment, we specifically attended to the affordances we were creating for students' engagement with content by creating opportunities for students' *procedural, conceptual*, and *critical* engagement. *Procedural* engagement, drawing on Pickering's (1995) notion of disciplinary agency, involves using procedures accurately. As has been documented in the TIMSS study, this is a commonly observed practice in American classrooms (United States Department of Education: National Center for Education Statistics, 2003), with students often practicing accurate use of procedures, often without knowing when to use the procedures, or why one might procedure might be more useful than other. In contrast, *Conceptual* engagement involves knowing what to do, when to do it, and why it makes sense. Similar to Pickering's (1995) notion of human agency, conceptual engagement captures the work of sense-making in mathematics. It is this level of engagement that is the goal of many reform programs, which seek to support students to, for example, "learn with understanding" (National Council of Teachers of Mathematics, 2000). Finally, *critical* engagement requires interrogating the usefulness, impact, or consequentiality of the selection of particular tools on outcomes. These different ways of engaging are not separable, but rather cumulative—conceptual engagement cannot occur without a robust understanding of procedures; likewise, one cannot critically engage without having a conceptual understanding of content. Our purpose in attending to these three levels of engagement is to provoke dispositions towards engaging statistics: *procedural* dispositions involve using procedures accurately and viewing justification and evidence as crucial components of convincing arguments; *conceptual* dispositions involve viewing representations as reflecting real phenomena, as opposed to simply numbers without meaning, and *critical* dispositions involve viewing operations and representations as tools that can be intentionally leveraged to develop and support particular arguments. We conjecture that dispositions develop through students' engagement with content in contexts, and involves: (1) adopting disposition-relevant goals, (2) becoming knowledgeably skillful to achieve those goals, and (3) attuning to the affordances of situations in which that knowledge is useful. One question addressed by the larger project is how many experiences with materials are required to develop a new disposition towards engaging, and what kinds of tasks and contexts afford the realization of this trajectory.

The work discussed here represents the first of many planned rounds of conjecture testing and revising. Like many design experiments, the purpose of this study was to advance both theoretical and pragmatic understandings (Barab & Squire, 2004; A. L. Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003), and thus to not only to engender the development of particular dispositions in students, but also to more clearly conceptualize the mechanisms associated with the development of these dispositions. Specifically, our goal was to better understand how particular design choices afforded particular forms of engagement, and how other aspects of classroom practice shaped the ways that students recognized or took up those affordances. The questions addressed in this first round of implementation are listed below; other questions that will be addressed in future implementations are discussed in the implications section.

- What design decisions promote intended aspects of engagement?
- *How* do these designs promote engagement?
- Are there some ways of engaging that are easier to support than others?

The designed curriculum

The Quest Atlantis Project (www.QuestAtlantis.org) is an educational videogame that uses a 3D multi-user environment to immerse children, ages 9-12, in meaningful learning trajectories across multiple disciplines. QA is a highly researched curriculum that has been under development for the last five years (Barab, 2007; Barab, Jackson, & Piekarsky, 2006; Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005). The QA virtual environment involves engaging dilemmas and consequential narratives which provide an overarching structure that lends form, meaning, and cohesion to a collection of activities, each with its own identifiable rules and challenges. Through the design of academically useful and motivating spaces, we can position elementary students within rich worlds where they act with agency and consequentiality and use disciplinary knowledge to solve meaningful tasks.

Multiplayer educational games create several opportunities for student engagement that are frequently lacking in traditional schooling. In Quest Atlantis, students take on particular roles and engage various plot lines, which can evolve and change based on the choices that they make. In this way, students are central players in an unfolding storyline that requires participation in academically meaningful activities, either in the real or simulated world. Thus, although students are "playing," their actions have more consequentiality than their "real world" interactions in schooling. Play, in particular, affords many robust opportunities to form new and different relationships to content, because of the repositioning of the student in relation to content (Gadamer, 1975; Vygotsky, 1967). As a consequence, a player's *dispositions* may be modified if the game is successful in its invitation to examine and reexamine the meanings of the design. In this way, well-designed videogames hold the potential to position students in relation to content in particular ways by affording different kinds of engagement, while simultaneously setting out a trajectory of participation that has implications for more enduring relationships with content and a new way of seeing the world (Gee, 2003; Lee & Hoadley, 2007; Shaffer, 2006).

City Statistics

The statistics unit designed for Quest Atlantis, called *City Statistics*, takes place in Normal Village, and was created to support students' engagement with the following content standards (NCTM, 2000):

- Select and use appropriate statistical methods to analyze data.

- Describe the shape and important features of a set of data and compare related data sets, with an emphasis on how the data are distributed;
- Use measures of center, focusing on the median, and understand what each does and does not indicate about the data set;
- Compare different representations of the same data and evaluate how well each representation shows important aspects of the data.
- Develop and evaluate inferences and predictions that are based on data.
- Propose and justify conclusions and predictions that are based on data and design studies to further investigate the conclusions or predictions.

As the unit begins, students are summoned by the leader of the city council to help in a time of crisis for Normal Village. Students are told that the citizens of Normal Village are leaving because of poor living conditions. In an attempt to improve the quality of life for its citizens, the city council wants to make some changes, but they need help making decisions about three issues: which brand of swings they should purchase for the park in order to maximize their longevity; which brand of bicycle the city should offer for rental based on which is the safest; and what items should be in the park's snack stand in order to maximize profit but minimize conflict among parents and children. The council stresses that they need recommendations that are defensible—based on evidence, not just opinions. Students are hired as statistical consultants whose task is to make recommendations to the city council about what they should do with respect to three central issues. In order to make these recommendations, students encounter various stakeholders who have different opinions and resources that are useful in evaluating the pros and cons of each decision. All dilemmas are designed to support different conclusions depending on the statistical method leveraged for analysis (e.g. students might make a different recommendation if they calculate the mean of a data set than if they consider the mode or look at the distribution of the data set). As students help to redesign the city by making arguments for or against particular decisions, they engage with increasingly advanced statistical content, and are challenged to offer increasingly sophisticated explanations and justifications of their decisions.

The unit was designed to afford three levels of engagement: Procedural engagement was afforded by creating opportunities for students to use statistically based reasoning accurately, for example by calculating measures of center correctly. Conceptual engagement was afforded by creating opportunities for students to explain why their recommendations were sound and believable, both through explicit instructions in activities, and by evoking an external evaluator (the city council) who needs to understand why different recommendations are made, in order to have sufficient information to make a decision. Finally, critical engagement was afforded by creating activities that had more than one possible recommendation, so that students could compare the implications of their method of analysis on the way the situation was ultimately represented, and the resulting conclusions that they drew.

Methods

The study was conducted with 25 students in a 6th grade class in a small city in the Midwest. Students in this class had some experience with Statistics from their regular mathematics curriculum. Many students were familiar with the definitions of mean, median, and mode, as evidenced by their work on the first assignment of the unit. All students had previous experience with the Quest Atlantis 3-D environment.

The intervention unit, Normal Village, was implemented during the students' technology time, and was taught by the first author, rather than the students' usual teacher. The unit took 8 days to cover over a two-week period. Students worked independently at computers, although they communicated with other students through informal talk to others seated nearby, and through chat and e-mail functions that are an integral part of the Quest Atlantis environment. Students had three Quests, or analyses, to complete. Each Quest was reviewed and either accepted or returned for revision. Students could not fail the Quests, and had multiple opportunities to revise. Although students worked at their own pace, the entire class gathered together after most of the students had finished each Quest to share different findings and reflect on justifications, implications, and remaining questions.

Data collection

Three forms of data were collected: (1) video of individual student participation; (2) video of whole-class conversation; and (3) records of student work. Three pairs of students were videotaped every day as they worked through the unit; the pairs were chosen to represent a heterogeneous selection of the classroom, with male, female, high-, and low-achieving students captured. When whole-class discussions were videotaped, the camera was stationed at the back of the room, in order to capture the greatest number of students possible. Students' work, which is the primary source of data discussed in this paper, was collected and evaluated initially through the Quest Atlantis system, and then later coded according to the themes discussed below.

Analysis

Three Quests per student were collected and coded in order to capture students' engagement with content. Some codes were created apriori, according to the envisioned categories that the curriculum was designed to foster. Other categories were emergent through our review of the activities (Strauss & Corbin, 1990); this was appropriate based on our desired goal to understand how particular elements of the designed curriculum supported both envisions and unimagined ways of engaging. For the purposes of this paper, we are limiting our discussion to the apriori defined codes. We coded for students' procedural dispositions by attending to whether students explained how they knew that they used their chosen method accurately (method accurate). Notably, this is a very high standard for procedural understanding, as many students are accustomed to allowing their work to stand alone without explanation of how they know that their work is accurate (heard, for example, in the oft-repeated phrase: "if it's right, why do I have to explain it?). Thus we are not attending here to whether students *used* the procedures accurately, but rather whether they explained how they knew that they had used the procedures accurately. We coded for conceptual dispositions by attending to whether they justified their conclusion by telling about the tools they used (justify), and we coded for critical dispositions by attending to whether they justified the *choice* of method that they used in their analysis (justify method) , and whether they connected their recommendation to the real world of the scenario (real world). Codes were created and refined by two coders, and were coded independently, with an initial agreement of 70%. Disagreements were resolved by discussions between the coders until consensus was reached. For the purposes of this initial round of analysis, we looked only for evidence of the style of students' engagement, rather than attempting to determine whether or not they had developed dispositions. The implications of this distinction are discussed below.

Results

The results of students' procedural, conceptual, and critical engagement are discussed below. Tables 1-4 depict the counts of codes for each Quest. The coding scheme allowed for a code to only appear once per quest; so in Table 1, 3 instances of "explain" for method accurate in Braking Distance means that 3 students explained how they knew that their procedure was accurate in the Breaking Distance Quest.

Procedural engagement

> "*What made me decide to choose the WURK brand swings was one of the graphs that I saw. It was the sorted data graph and it showed that the WURK brand swings have more consistent time that they lasted than c3 brand swings do. The WURK brand swings lasting time range was eight, and the c3 brand swings lasting times range was twenty-seven. I think that it is better to have a swing brand whose swings will always last for about the same amount of time so that you can estimate the number that you need to buy and so you don't get a few bad and short lasting swings with long lasting ones.*" (Male student, coded "explain")

Students' procedural engagement was captured by examining whether and how students' explained how they knew that they had used procedures accurately to lead to their conclusions. As seen in Table 1, in the first activity very few (3/26) students correctly explained how they knew that they had used procedures accurately, despite the fact that all 26 students had used some kind of method to analyze the data. This trend changed over the activities, with more students justifying the accuracy of their procedures in the 2nd (16/26) activity. However, there was a decrease in the percent of students who justified their procedures in the final activity, with only 10/25 students explaining how they knew that their method was accurate. One conjecture that might account for this difference comes from the nature of the activity itself, which is discussed below.

Table 1: Students' justification of accurate use of procedures.

	Breaking Distance	Swings	Snack Cart
Explain	3	16	10
Incorrect	2	1	1
No mention	21	8	13
No method	0	1	1

Conceptual engagement

> "*With the information, we made a bar graph comparing the two brands. In the graph, you can easily see that the Speedy Spokes take a lot less time to stop then (sic) the racy Rider. The Speedy spokes on average got 38.3 feet before they stop. The Racy Rider got 53.10 feet before*

they stopped. Since the object of this was to have the shortest length before they stop, the Speedy Spokes beat the Racy Riders by 15.8 feet. Thus from this data, the Speedy Spokes are a safer brand of bikes to ride" (Male student, coded "justification")

Students' conceptual engagement was captured by examining their use of justification, and their connection of the scenario to real-world implications. Table 2 illustrates students' use of justification. A very low standard was used for this code; we were interested in learning simply if students went beyond making a recommendation to include WHY they had made their recommendation. All students used justification throughout all three activities. This might be due to the nature of the activities, which all explicitly asked students to make a recommendation and explain what evidence they are drawing on to support their ideas. In addition, it might be due to something external to the curriculum, and students might have been very accustomed to using justification in all mathematics activities. In a similar trend, a dramatically increasing number of students began to refer to the real world of the scenario in their justifications, suggesting that students were using disciplinary content to make sense of particular situations (see Table 3). This is an important element of critical engagement—seeing your actions as having implications on the real world.

Table 2: Students' use of justification.

	Breaking Distance	Swings	Snack Cart
Yes	26	26	25
No	0	0	0

Table 3: Students' connection of their recommendation to the scenario.

	Breaking Distance	Swings	Snack Cart
Full	7	11	19
Mention	19	8	6
No Mention	0	7	0

Critical engagement

"*Yes, I do think that the candy made a difference to the sales, in a positive way. From your first look at the graph, it is quite clear to observe and see that the clump of data points in July, the sale amounts that were most common for that month, moved to the right in August, meaning that the common sale amount for August was higher, when the candy was introduced. Interestingly, July sales ranged from $.80 to $2.70, while the sales for August ranged from $.40 - $2.70. Although candy seemed to help the snack cart's sales, when candy was actually introduced, some sales became smaller, making the range $.40 to $2.70. In July, no sales were as little as $.40, which makes you question whether candy really did help the snack cart's sales. To get down to the precise answer of this question, it seems logical to calculate the total amount of sales for each month. In July, the total sale was $153.05, while the sales in August were $164.75. This shows that candy did help the snack cart's sales; however, the snack cart also lost some adults who enjoyed the healthy snack, and didn't allow their children to buy much candy. Therefore, although candy raised the sales, I do not think it is the solution to increasing sales."* (Female student, coded "relevant for situation" for choice of method)

Students' critical engagement was captured by examining whether students explained how they had chosen their particular methodology, or even that they had been aware that there was a choice to be made (see Table 4). In the first activity, half of the students began by explaining how their method was reasonable based on the situation that they were trying to understand. By the second activity, there was a slight change, with 5 students attempting to explain how they chose their method, but not doing so in a robust way. However, similar to the trend observed in Table 1, students' use of justification decreased in the snack cart activity, with only 12/25 justifying their choice of method.

Table 4: Students' justification of their choice of method.

	Breaking Distance	Swings	Snack Cart

Relevant for situation	14	15	11
Good	0	5	1
Arbitrary	6	4	6
No justification	6	2	7

Discussion

The results of this first round of implementation were both exciting and surprising. Although our analyses suggested that the kinds of engagement we had designed for were realized in the transition between the first and second activities, there was little evidence of change in the desired direction in the final activity. These disparities speak directly to our first question of which design decisions promote particular forms of engagement. Specifically, we found that the progression we developed appeared to support productive, conceptual, and critical engagement—but only within the first two activities. When unpacking students' engagement with these activities (question 2: *how* did the designs promote particular forms of engagement), we found that role of context in problems was perhaps not quite as straight-forward as we had originally thought. Although it was clear that the context served as a significant resource for students to consider the implications of their decisions, it appeared that it could also be a distraction.

This could be seen in students' justifications and arguments in the final snack cart activity. This activity dealt with the issue of whether or not the town should include candy in their snack cart. The debate was about whether or not candy raised sales, and whether or not candy raised sales *enough* to warrant making some parents angry. During the last year American schools have by and large removed candy, sodas, and other high-sugar content snacks from the premises, even banning them from being brought for celebrations or sent in home-packed lunches. Many school children are aware of the issues at play in the debate, so we designed the Snack Cart scenario with the hopes of leveraging prior knowledge and experience to enrich the arguments brought about in our design. However, we found that the context was so enticing that the mathematical practices and properties of the Quest did not take hold of the students. Their focus lay on the contextual particulars and how they might play out in a social setting, rather than the analytic setting we proposed to them. This is consistent with findings from other studies, which suggest that extremely context-rich problems create new challenges for curricula, and therefore must be used only if the contexts support equally complex kinds of problem solutions, which our design did not (Boaler, 2002; Silver, Smith, & Nelson, 1995). We suggest that the shift of five students who explained their justification in the 2nd Quest to those that failed to even mention a justification of their method in the 3rd is correlated to the overwhelming emotional attachment to the context. This was evidenced by students' use of personal examples in their justifications, which was not seen in earlier submissions.

This study also set out to address whether there might be forms of engagement that are easier to support than others. We conjectured that it would be most challenging to support students to engage critically with content, and students' responses on the Quests bore this out. Interestingly, although students seemed connected to the real-world implications of their decisions, they did not use analytic tools as a means of intentionally affecting those situations. There are a few possible explanations that we will consider ways of drawing out in our next design iteration. The first is that students do in fact know how to state testable hypotheses that expose their understanding of the meaning of methods such as calculating the mean versus the mode, and where, when, and why each calculation might be desirable, but our design did not make that request visible enough. The second is that the students may never have been placed in the position of having agency to select and determine the utility of a particular method from among others. The third is that schools are teaching a variant methodology that does not clarify the need of accounting for a methodology. This suggests a lack understanding that hypothesis generation and testing, or the methodological need to externalize pre-conceptions of experimental results is part of an analytic process. In personal communications with the class teacher she suggested that students are both implicitly—by the design of high-stakes exam questions—and explicitly—through the training and educational environment that has emerged—being taught that to justify is to provide an explanation of what was done to arrive at the final decision. This explanation need not include the description of what was tried unsuccessfully, or any notion of a negative result.

Implications for future iterations

The results of this first round of implementation have raised new questions and supported the development of different conjectures. The next design iteration will focus more centrally on students' critical engagement by designing activities that more strongly afford opportunities for students to interrogate the role of particular analyses on different conclusions. This could be accomplished, for example, by positioning students as "critical consumers," who need to evaluate the data-driven claims of different advertisers.

We are also mindful that two centrally important aspects of the development of dispositions have not yet been adequately addressed. First involves the notion of what evidence of adopting a disposition might look like. If someone has developed a disposition, how would you know? Can it be seen in one performance, or can it be seen only by looking across multiple activities? For our current purposes, we looked at styles of engaging over the course of a unit, examined whether evidence of change could be seen. The follow up question is whether observed changes are persistent, and under what conditions the continuities emerge. Second, we found the difference in students' performance on the final activity to be a particularly telling event, challenging our ideas about how dispositions develop. One might argue that students' performance on the final activity suggested that a disposition did *not* develop, as the emergent pattern did not continue. This leads to a different question of how long it takes for a new disposition to develop—can it be fostered through one or two influential experiences, or is it a change that is more gradual, requiring systematic opportunities to engage over time?

Finally, once we feel confident that we can successfully foster robust productive, conceptual, and critical dispositions, we will address whether dispositions towards engaging are related to different relationships towards knowledge. Specifically, we will investigate whether dispositions are related to other knowledgeable performances, seen both in related activities, and more conventional measures of understanding.

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