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Implementing Classroom Reform in Science: What are our goals?

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Science education has taken a turn. "Hands-on" or "discovery learning" activities have been replaced with more authentic, student-centered problems that are less structured and less teacher-directed. Whether it's called Problem-based Learning or Technological Design, one theme seems clear: constructivism has become a driving force in science education. In support of this trend, the National Research Council recommends a de-emphasis of "student acquisition of information" and teacher "present(ation of) scientific knowledge through lecture, text, and demonstration" (Kahle, 1996, p. 274). In turn, the Council endorses more emphasis on "student understanding and use of…inquiry processes," as well as "guiding…students in active…scientific inquiry" (p. 274). These recommendations are consistent with the learning principles of constructivism as well as their application through problem-based learning activities (Gallagher, Sher, Stepien, & Workman, 1995). It is still unclear whether intentions to promote student-centered learning have been effectively translated into practice (Finson, Fitch, Lisowski, & Foster, 1996). This application of constructivist learning theory into living, breathing science classrooms has proven problematic and complicated to say the least (Davis & Sumara, 1997). Recent research and discussions concerning constructivist-based science curricula have explored student attitudes, specific cognitive models for student learning, and limitations of the learning theory for science education (Weaver, 1998; Appleton, 1997; Osborne, 1996). Consideration of what the long-term goals are for the constructivist classroom is an important component in the development of reforms in teacher preparation. For many teachers, this is a scary recommendation: less control, more preparation, and more complex assessment. What are the implications of moving from student-centered science to teacher directed reading and math? What resources need to be made available at the school, state, and national level? Is the system ready to support these recommendations by putting its money where its mouth is?

Consider constructivism as a theory of learning. Constructivism presents a particular view of the relevant characteristics of the learner as well as the learning process. von Glaserfeld (1989) identified three themes in the constructivist view of knowledge: knowledge as individual, knowledge as constructed, and knowledge as resulting from social interaction. Piaget has been a pioneer in this conceptualization of the learner as an active agent who creates knowledge rather than a passive recipient of information. But more than just a philosophy for guiding instruction, constructivism is a theory of knowing with specific assertions about the nature of the student as knowledge-maker and the process of learning in general. But where does the teacher fit into this "new" science learning environment? Vygotsky's (1978) conception of the zone of proximal development explains the importance of teacher-student and student-student learning relationships. Basically, the zone is the difference between the learner's actual developmental level and his/her potential or future development "as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). When the learner is given support by the teacher, he/she is able to accomplish understandings that would be impossible without this scaffolding. The above characterization of the learner and learning process has important implications on the design of instruction. But more importantly, the tenets of constructivism require teachers to espouse a very particular view of learning. What happens if teachers implement these authentic problems as lessons without adopting the corresponding theoretical framework upon which it was built?

So, the question remains: what are the goals for classroom reform in science education? Is the change of the teacher's role in the class from expert knowledge-transmitter and student "manager" to co-constructor and guider the goal across the entire curriculum? Dana, Campbell, & Lunetta (1997) describe the changing nature of teacher competencies in these constructivist learning environments. "Teachers must shift their attention away from themselves as effective presenters of scientific information toward a focus on students' developmental needs to learn science with understanding" (p. 424). Hand (1996) documents this shift as teachers in his study transition through five stages, from "managers" to "facilitators" and "empowerers" (p.217). In Stage 1 (Manager Role), teachers focus on information transfer; their main concerns are about classroom control. In Stage 2, teachers begin to recognize the mismatch between students' and teacher's conceptions of a topic or problem. Stage 3 (Technician Role) teachers focus on following implementation process for constructivist approach rather than on the effects of this approach on students' learning. Stage 4 (Facilitator Role) teachers have increased confidence in the constructivist approach resulting in a decrease in teacher-controlled activities. Finally, in Stage 5, teachers allow students to become problem-setters, not just problem-solvers. This is the role of the "empowerer" (pp. 216-219). Is this our expectation for teachers?

Not only does teacher behavior change as a result of this shift in learning theory from knowledge receiver to knowledge builder, but student behavior has changed as well. Beeth (1998) examined the metacognitive dialogue of students and teachers to better understand students' conceptions of such science concepts as force and motion. He points asserts that "these new (teacher) roles required that this teacher provide, and that her students apply, metacognitive tools when engaging in learning as conceptual change" (p. 355).

With these reforms in science being disseminated and implemented into classrooms, practical questions about their implementation arise. The very definition of science literacy is changing from content knowledge to cognitive competencies (Hurd, 1998). What are the limitations of authentic instruction, not as a learning theory, but as an applied curriculum delivered by teachers in science classrooms? Several authors have supported problem-based learning in both elementary and secondary science as well as in higher education (Aspy, Aspy, & Quinby, 1993; Glasgow, 1997; Marx, Blumenfeld, Krajcik, & Soloway, 1997; Weaver, 1998; West, 1992). However, many have discussed the serious political, historical, and practical implications of broad science curriculum reform (Hertzog, 1997, Marx et al., 1997; Tippins, Nichols, & Weiseman, 1998). Some of these issues include conflicting values of the participants of such reform, like administrators, teachers, and parents. Not only do different participants have different vantage points from which they view the reform, but they also have different notions of who has power to implement change (Tippins et al., 1998). Finally, teachers experience barriers to successful implementation of authentic instruction in many arenas, including time, loss of control, classroom management, effective student scaffolding, and assessment (Marx et al., 1997). Glasgow (1997) emphasizes the need to "view education as a process…as well as a body of knowledge, techniques, and other processes" (p. 68). Systemic resources for support of teachers implementing problem-based learning, might take the form of time for collaboration between teachers that is structured into the schedule as described by Glasgow. The important point is that teachers are working within a system of people and resources that promote rather than drain their ability to implement the problem-based curriculum in a wider scope.

This paper begins with a discussion of one project funded by the Illinois State Board of Education designed to facilitate the implementation of technological design as defined in the National Science Education Standards. The staff development model promotes the use of technological design projects to enhance scientific literacy of students in grades 3 through 5. The discussion focuses on three general questions related to the implementation of technological design in science education:

1. Do teachers need to recognize constructivist theory in their practice?
2. What are we looking for in terms of technological design effectiveness? Should we focus solely on science literacy or are their other notable outcomes?
3. What are the parameters for implementing technological design (assuming we determine its effectiveness)? What do teachers see as the "place" for technological design in their curriculum?

Method

Sample

The application of technological design principles in 11 classrooms was assessed through classroom observation and interviews. Teachers' classrooms were visited while students were engaged in the design, construction and fair testing of the design projects. Both the teacher and students were observed to determine their instructional, learning, and non-instructional activities. Reflection on various issues related to the implementation of technological design was obtained in interviews of two teachers.

<u>Data Sources</u>

The observation instrument utilized fixed categories codes to record teacher instructional and non-instructional activities as well as student learning, non-learning and off task codes. The material used by the teacher and students were also coded. The activity and material codes reflected both general activities (lecture, discussion, questioning, etc.) and project specific activities (discovery, problem solving, critical thinking, design project material, etc). These codes provided a scaffold for reflecting on the classroom management issues faced in the technological design curriculum.

Codes of teacher and student activities were recorded at 5 minute intervals through the observation. At each interval a visual clockwise sweep of the classroom was made and the activities of the teacher and each student was recorded using the codes. These codes were entered on a sketch of the classroom to indicate the location of the teacher and students as well as the activity that occurred. Between the sweeps, narrative comments were recorded to assist in the analysis and interpretation of the data. These comments provided a context for the individual codes that were recorded.

Finally, interviews were conducted with two teachers who approached the implementation of technological design differently (while still within the parameters of the design guidelines). These teachers' reflections were recorded, transcribed, and analyzed to identify loose themes in their understandings of classroom management issues, among other topics, in a technological design classroom.

Data Analysis

Frequency of student and teacher behaviors were tabulated for each coded activity by the researcher who conducted the observations. Analysis of interview data was conducted separately by the first author, who was not present in the field. Validity of themes emerging from qualitative analysis was triangulated with coded observations and member check with the researcher who conducted the observations.

Results

Teacher and student activity codes were tallied to determine the percentage of time engaged in instructional and non-instructional activities. All 11 classrooms were engaged in science activities from the technological design curriculum during observation. For students, the results indicate that most behaviors recorded were related to learning rather than non-learning activities. Specifically, approximately 85% of student time was spent engaged in learning activities of various sorts; the remaining 15% of student behavior was coded as some kind of learning-related activity (about 12%) or off-task behavior (<2%) (see Appendices A and B).

Some interesting trends emerged from the interviews with two participating teachers. Issues they raised were varied and included classroom management, their new roles in the classroom, student learning in technological design projects, and the use of these projects both in science and in other areas of the curriculum. Both teachers expressed concerns about the impression outsiders would have about their classes. There were also differences embedded in the teachers' descriptions of their roles. Both teachers struggled with transitioning from "manager" to "facilitator," and described the stresses inherent in this new pedagogical framework. Also, student performance differences were described by one teacher in particular. The effectiveness of technological design for certain students was considered as well as possibilities for diagnosing problems and creating solutions. Finally, the teachers reflected on the feasibility of technological design for science in particular and elementary education in general.

1. Do teachers need to recognize constructivist theory in their practice?

What does it mean for a teacher to "implement" technological design projects (or similar authentic instruction) without adopting the underlying paradigm? While both teachers talked about their new role using metaphors like "coach" and "mentor," there seemed to be a difference in the amount of true "student control" being promoted. It is difficult to say whether there truly was a difference in the degree that the teachers adopted the constructivist framework. However, one teacher seemed to be much more planful of how students would engage in the "open-ended" problem of creating parachutes.

> *"I thought: instead of giving them exact plans in how to make parachutes this is where I thought the design would come in…and then after they've done that, I will give them questions" (Teacher B, interview transcript).*

Compare this with a teacher who describes the process in her classroom:

> *"I really try to let the questions come from the students and that…decide where we're going to go" (Teacher B, interview transcript 1).*

Do these teachers have a different conception of the underlying theoretical framework? If so, do student outcomes reflect these differences? In Appendix C, the data for student activities across all eleven teachers is presented. Note that for Teacher A, 92% of student activity that was observed was coded learning versus 86% for Teacher B. In addition, only 2% of student activity was coded as non-learning for Teacher A while 11% was coded for Teacher B. These data show potential differences between the students behavior in the two classrooms. Do they reflect a different value system of the teachers? It is hard to say.

2. What are we looking for in terms of technological design effectiveness? Should we focus solely on science literacy or are there other notable outcomes?

Both teachers expressed the notion that the students gained in ways that were qualitatively different from more traditional outcomes.

> *"It also gave these kids an opportunity to demonstrate something that wasn't just direct knowledge paper/pencil kind of task" (Teacher B, interview transcript).*

These outcomes were also often described in terms of transferring and applying knowledge to other tasks.

> *"When I presented this…alarm for the chicken coup, I didn't say, 'you know you're going to have to make sure that it's connected to your energy source'…I didn't have to say all those things…those were already things they knew. So they showed me that they knew it by applying it" (Teacher A, interview transcript 1).*

Finally, not all of the outcomes were science-related. They included more social or affective development.

> *"…it could even be social-wise. Was cooperative, you know, helped the group come to a decision. Was kind of a peace-maker or you know...they worked well with their team during the process…(Teacher A, interview transcript 1).*

Again, data in Appendix C is helpful for understanding student outcomes in terms of student engagement in the learning tasks. Note that an average of only 4% of student behavior was coded off-task while 87% of student behavior was coded as learning.

3. What are the parameters for implementing technological design (assuming we determine its effectiveness)? What do teacher see as the "place" for technological design in their curriculum?

Not surprisingly, teachers did not rally behind the suggestion of implementing technological design beyond science. Some of the concerns were related to meeting the needs of the curriculum.

> *"It's hard to find things that fit our curriculum too. Not everything fits as easily with technological design. It's you know…it's hard to find a project" (Teacher A, interview transcript 1).*

Other concerns related to the time and energy requirements that these projects inevitably take.

> *"I think they're moving to looking at subjects in other ways…But I…I really think that if I taught every subject like I teach science, I would be exhausted" (Teacher A, interview transcript 1).*

These are very practical concerns that are commonly expressed by teachers engaging in student-centered instruction. The bigger question is, will education change to support and address these issues to make successful implementation a real possibility.

Discussion

As technological design (as an application of problem-based learning theory) begins to work its way into science curriculum and answers to questions about its effectiveness emerge, the scope and context of implementation need to be addressed. In addition to the classroom observation data, interviews with two teachers provide initial understanding of their perceptions of the role technological design can and should play in their classrooms (two very different questions). Marx et al. (1997) warn that “new ways to deal with subject-matter content, activities, time, classroom management, and organization must be explored” (p. 355). Successful models of student-centered curricula (see Glasgow, 1997; Hertzog, 1997) should be studied and the broader pedagogical, political, and systemic implications need to be addressed.

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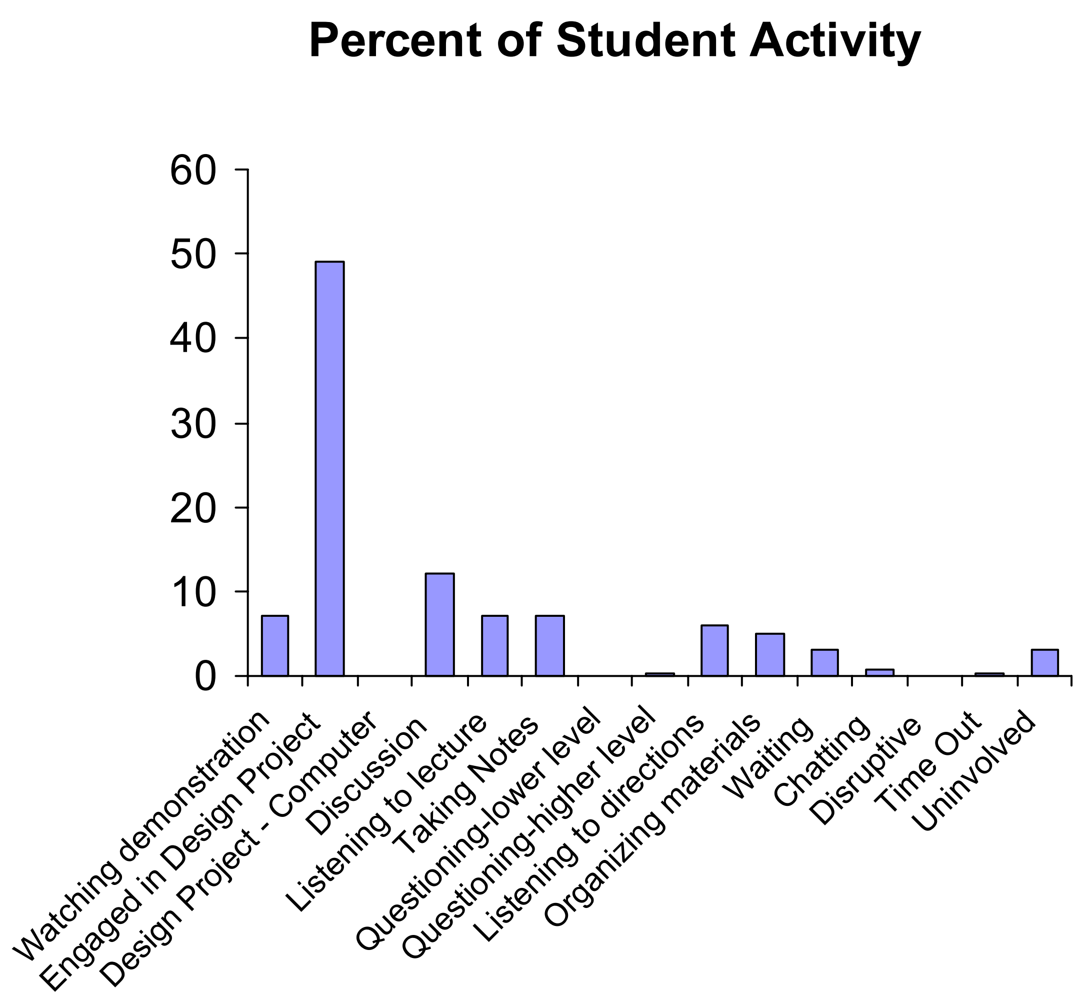
Appendix A

	Student Activity	Average Percent of Students' Activity
Student Learning	Watching Demonstration	7
	Designing/constructing/testing/revising	49
	Design activities w/computer	.07
	Discussion w/peers	12
	Listening to lecture	7
	Taking notes	7
	Questioning-lower level	.1
	Questioning-higher level	.3
	Listening to directions	6
Learning-Related	Organizing materials	5
	Waiting	3
Non-Learning/Off-Task	Chatting	.8
	Disruptive	.09
	Time out	.2
	Uninvolved	3

Appendix B


Percent of Student Activity
60
50
40
30
20
10
0
Watching demonstration
Engaged in Design Project
Design Project - Computer
Discussion
Listening to lecture
Taking Notes
Questioning-lower level
Questioning-higher level
Listening to directions
Organizing materials
Waiting
Chatting
Disruptive
Time Out
Uninvolved

Appendix C

Percentage of Each Student Activity for Each Class

	A	B	C	D	E	F	G	H	I	J	K	Average
Student Learning Codes	**92%**	**86%**	**54%**	**69%**	**96%**	**97%**	*** F**	**93%**	*** H**	**95%**	*** J**	**87%**
DeDp Watching Demonstration of Experiment/Project	.6%	2%	0%	0%	0%	14%	* F	12%	* H	11%	* J	**7%**
Dc Designing/Constructing/ Testing/Revising the Design Project with Teacher/Peers	44%	36%	28%	62%	84%	35%	* F	50%	* H	57%	* J	**49%**
DcC Design Project Activities Using a Computer	0%	0%	.8%	0%	0%	0%	* F	0%	* H	0%	* J	**.07%**
Di Discussion with Teacher/Peers	27%	1%	17%	6%	11%	16%	* F	9%	* H	10%	* J	**12%**
Li Listening to a Lecture/ Presentation of Teacher/Peers	8%	30%	0%	0%	0%	7%	* F	13%	* H	0%	* J	**7%**
N Taking notes during a Discussion, Lecture, Media Presentation or Design Project	5%	15%	8%	1%	1%	15%	* F	3%	* H	3%	* J	**7%**
QL Questioning-Lower-Knowledge/Information	0%	1%	0%	0%	0%	0%	* F	0%	* H	.1%	* J	**.1%**
QH Questioning-Higher-Analysis/ Synthesis/Evaluation	.9%	1%	0%	0%	0%	.5%	* F	.3%	* H	0%	* J	**.3%**
D Listening to directions	6%	0%	0%	0%	0%	9%	* F	6%	* H	14%	* J	**6%**
Student Learning Related Codes	**9%**	**5%**	**33%**	**29%**	**3%**	**1%**	***F**	**4%**	***H**	**2%**	***J**	**8%**
OA Organizing/Arranging students/materials/supplies	9%	3%	21%	11%	3%	1%	* F	.5%	* H	2%	* J	5%
Wt Waiting	0%	2%	12%	18%	0%	0%	* F	4%	* H	.3%	* J	3%
Student Non-Learning Off Task Codes	**2%**	**11%**	**14%**	**3%**	**1%**	**1%**	***F**	**3%**	***H**	**2%**	***J**	**4%**
C Chatting	0%	4%	5%	0%	0%	0%	* F	0%	* H	0%	* J	.8%
D Disruptive	0%	0%	0%	0%	0%	0%	* F	0%	* H	.5%	* J	.09%
TO Time Out	0%	0%	2%	0%	0%	0%	* F	0%	* H	0%	* J	.2%
U Uninvolved with Teacher/ Peers/Intended Activity	2%	7%	7%	3%	1%	1%	* F	3%	* H	2%	* J	3%