CoreModels Final Report (9707702) Findings

Introduction

Funding for CoreModels was provided by the National Science Foundation through the Research on Education, Policy and Practice (REPP) program. As a research project, the CoreModels Project has investigated two questions. Can computational modeling activities help students achieve core learning goals? In order for such activities to help students, they must actually be implemented in the classrooms. Thus the CoreModels vision stressed a high rate of effective implementation. This led to our second question. Can teachers support their peers in implementing these activities? Our findings indicate that peers (or the community) can be effective in supporting teachers in enacting modeling activities. The first two sections of this report presents our findings for these two questions.

As discussed in the *Activities* section of this report, teacher leaders guided the development or adaptation of biology activities including deer population dynamics, the carbon cycle, stream water quality, glucose regulation, natural selection, human genetic conditions, and enzyme reactions. Physics modeling packets were designed to help students investigate kinematics, dynamics, momentum, applications of force, free fall, projectile motion, universal gravitation, and Newtonian cooling. In earth science, the project created activities focusing on the water cycle, the rock cycle, erosion and soil loss, earth energy balance, hurricanes, volcano ash transport and orbits. Chemistry packets included radioactive decay, diffusion, kinetics, chemical equilibrium and Rutherford's gold foil experiment.

Creating and revising modeling activities became a “radically more time-consuming process than the program leaders had originally envisioned it to be. Developing, testing, refining and disseminating units became an all-consuming task for a small subset of the teachers, while many other teachers dipped in and out of the process, devoting considerable energy to the process when a unit was under development that fit particularly well into their curriculum.” (Friedman & Culp, 2001). But this process “played a crucial role in driving the evolution of teachers’ thinking about modeling and systems thinking over time.” Thus, the final section of this report considers the successes and difficulties of activities development and its role as intrinsic part of the peer-collaboration/community development process.

Peer Collaboration

As described above, center directors and supporting teachers met as a group several times each quarter during the first year of the project. In addition, directors made appointments to visit activity enactment by the supporting teachers or invited them to visit the director’s classroom. In addition to working out problems with the modeling activities, we were piloting the peer support component of the project. Supporting teachers understood that they would take on a mentor role during the next year. These twelve individuals (project director, CDs and STs) were highly committed to the project and were generally able to work through the difficulties involved in an assigned mentorship. Since the CDs were released half time, there was some flexibility in scheduling meetings with those they mentored. In addition, the directors had the luxury of long phone calls during year one to support each other in mentoring the supporting teachers.

The second year began with a carefully designed program of peer support, which involved pairing Supporting Teachers with Participant Teachers and encouraging regular classroom visits and discussions between each ST/PT pair. Because pairs were originally matched across schools, logistical challenges (travel time, being willing or able to miss one's own class time to visit another teacher's class) played a major role in keeping most of these relationships from developing. Unlike the center directors, who had a reduced class load, the STs had to take professional leave (paid for by the project) and arrange for a substitute. In addition, supporting teachers were uncomfortable in their role as a "mentor," especially since many Maryland districts had established mentoring relationships to help under-performing teachers. For this reason, teachers were generally unwilling to comment on or critique one another's practices, which they understood to be a primary purpose of observing one another's classrooms.

At the beginning of the second semester, directors met with supporting teachers to make mid-course corrections to the peer support paradigm. One teacher commented that:

> "The peer support portion of the project has been and continues to be a struggle. The association of classroom visits with evaluations by supervisors and administrators appears to be deeply ingrained. Teachers seem to be receptive to workshop-type sessions but less amenable to having other teachers visit. Most PT's seem to be anxious to collaborate. Workshops and regional meetings have been productive for all parties involved. In this setting, PT's seem to be more relaxed, creative, and analytical. Support seems to work better in a group situation unrelated to a classroom, more of a brainstorming session."

The second year evaluation report hypothesized that the supporting teachers might not feel capable in their role as mentor. But another teacher replied that he was comfortable in his ability to support participating teachers, but had not found a way to communicate. Several of the six participating teachers he was assigned did not return email. He said, "As a peer mentor, I do not believe that I should force myself upon the participating teachers. On the other hand, there is no way to know how the project is being implemented in the classroom if the participating teachers are not observed."

The mentors suggested several reasons for the lack of response of the new teachers:

- Teachers expect to be autonomous; another person in the room is an invasion of privacy.
- Teachers do not want to "burden" the supporting teacher without a significant need.
- The summer experience went well; participating teachers have everything they need.
- PTs do not invite others to observe since they cannot plan the computer use in advance.
- PTs don't recognize the need to document modeling activities in their classroom.

We realized that we had to reconsider interpersonal factors and explain the purpose of peer collaboration more carefully to all project participants. Instead of beginning visits to schools with classroom observation, relationships should develop first through pre-observation planning visits. Teachers might also refocus classroom observation with the ST acting as a helper and the CD observing both. Leaders also suggested post-implementation discussion of student difficulties and after school gettogethers to work on a new model or on assessment questions to supplement the modeling activity.

The main difficulty with the peer support paradigm was in scheduling visits between supporting and participating teachers. Center directors did visit participating teachers. Center directors were also extremely successful in working with teachers within their own schools. We were able to build on this success during the third year in accepting additional teachers from the current participating schools.

According to Friedman and Culp (2001), "What we did find was that teachers gradually shifted to intra-school, more informal forms of peer support, and the program followed the teachers' lead and instituted cross-discipline, within-school, team-oriented peer support structures during Year 3 of the program. This model seemed to function more productively for teachers."

For example, the five teachers who joined the project from a single school during year three provided a critical mass of interest and know-how in the school. In addition, the center director visited so often that she was considered an "adjunct faculty member." Anxiety levels were reduced when teachers saw the director planning with colleagues and teaching as well as observing in their classrooms.

Although they may not have considered themselves mentors, some of the supporting teachers demonstrated considerable leadership ability. The ST's were invaluable in facilitating small group discussions at district quarterly meetings. They developed discussion guides and other ways of providing structure and focus without inhibiting the full range of discussion issues. In addition to taking on increasingly prominent leadership roles within the project, they began outreach efforts within their schools and school districts in introducing teachers outside the project to modeling. Some became deeply involved in collaborating around modeling curriculum issues with other teachers. Friedman and Culp (2001) found that "The professional growth of this subset of program participants resulted in an expanded core group of teachers who were effectively leading the program and providing guidance to the larger cohort of teachers, strengthening an already strong group of teacher leaders and contributing to the persistent, gradual progress of the level and content of teachers' discussion of modeling over the life of the program."

Effect of Modeling on Student Learning

Each CoreModels activity was designed to meet the Maryland High School Science Core Learning Goals as well as the AAAS Project 2061 Benchmarks. At the same time that MVHS teachers were implementing these modeling activities, the Maryland State Board of Education (MSDE) was field-testing the Maryland High School Assessment (HSA) tests, the final piece of the state's systemic reform plan. The HSA includes both selected response items (e.g., multiple-choice) and constructed response items which require the analysis, synthesis, and written expression of ideas. There were early indications that CoreModels activities were effective in supporting student learning. One teacher was thrilled with the first in the district results of his students on an early test of the biology HSA. Another teacher received accolades for the outstanding results of his physics students on the Force Concept Inventory, administered as part of his concurrent participation in the Arizona modeling project.

MVHS leaders decided that constructed response items scored using the MSDE rubric would be particularly relevant to teachers and to state leaders. We would also be assisting teachers in providing practice to their students by using the constructed response mode to measure student understanding gained through modeling. Since teachers reported that, as a result of using the materials, they saw improvement in their students' ability to meaningfully interpret the graphical representation of data and understand the ability of a model to represent real world behavior, we sought to determine whether the teacher observations listed above were actually measurable. Two open-ended questions were designed for each activity in biology and physics. The first question presented the student with a graph produced by the STELLA model used to investigate a topic recently studied and asked the student to explain its meaning. The second question asked the student to evaluate the ability of the model to represent real world behavior. Both questions would be scored using the 5-point Maryland High School Science Rubric, the same one to be used on the High School Assessment exams. In the fall of 1999, we asked for teachers who could meet the following conditions:

1. Cover three MVHS activities during the second semester and administer an assessment after each one.
2. Send the original assessments to MVHS and keep a copy to return to their students.
3. Score the copies according to the Maryland High School Science rubric.
4. Return the scored copies to the students and discuss the answers before administering the next assessment.

Eleven biology teachers and four physics teachers responded to our request. Teachers with semester-long block classes were more likely to participate since they were beginning with new students. The teachers' experience with STELLA ranged from 1 to 4 years, and the classes ranged from Basic Skills to Advanced Placement. Eleven schools were represented in the study, six rural, four suburban, and one urban. In the summer of 2000, these teachers met together with project leaders to score the assessments formally after general training and practice scoring for each topic. Each question was subjected to blind scoring by two teachers, with a third teacher resolving discrepancies.

Biology Results

Mean scores on the graph interpretation question dropped significantly ($p<0.01$) between time 1 and time 3, while mean scores on the modeling heuristic question rose significantly ($p<0.01$). The drop in scores on the graph interpretation question may be attributable to the fact that the third quiz was given at the end of the school year when student motivation was low. The results above do not include several teachers who were not able to give the third quiz. When the entire group of teachers was considered, there was an increase in graph interpretation scores from quiz 1 to quiz 2 that approached significance ($p=0.055$). The results for the question concerning the ability of a model to represent real world behavior are more promising. Even when the majority of third quizzes were given late in the school year, the mean for quiz 3 was higher than the mean for quiz 1.

Is student performance on a question type related to teacher comfort with that question type? Graph interpretation is an area in which many biology teachers have difficulty themselves in using mathematically accurate terminology. The teachers recognize this weakness in their backgrounds and are eager for more opportunities to practice graph interpretation skills with their students. Although the modeling activities provide that practice, it is possible that teacher reinforcement in classroom discussions needs to be improved in order to see steady improvement in student performance. We cannot expect to see student gains if their teachers are not clear in their own expression of the meaning of graphs.

Question 2 requires a written description of the similarities and differences between the model and the real world. Although teachers were initially uncomfortable with this question, we know from anecdotal evidence that they do become more comfortable and increase their focus on model interpretation skills after the administration of the first quiz. Therefore, the large increase in mean scores from quiz 1 to quiz 2 is at least partially attributable to increased focus on model interpretation.

Physics Results

As exposure to modeling activities increased, it was expected that student achievement would increase on both quiz questions. The data did not support this hypothesis. We observed that the means for the graph interpretation question went down, while the means for the model interpretation question went up. Scores on question 1 decreased between quiz 1 and 2 for some classes and between quiz 2 and 3 for others. To explore possible reasons for this discrepancy, we looked at the content of the quizzes. Question 1, which involved graph interpretation skills, appears to be more highly sensitive to the effect of content than question 2. One teacher gave eight assessments (n=24) providing the opportunity to look at the interplay between exposure to modeling activities and the difficulty of the specific topic being covered. Student performance increased significantly on both questions 1 and 2 over the first four quizzes covering kinematics-related topics. The concept of force was introduced in the fifth modeling activity. For quiz 5, the student means dropped dramatically on question 1, but less so on question 2. Elevator, the topic covered on quiz 6, reinforced the concept of force. The student means on both questions 1 and 2 increased significantly. Therefore, it seems likely that the introduction of a new concept may play an important role in student assessments in spite of the number of previous exposures to modeling activities.

Although the increase in content difficulty has some explanatory value in the decrease in scores in moving from kinematics to dynamics, other factors cannot be dismissed. Question 2 required a written description of ways in which the computer model was similar to and different from the phenomenon it was meant to represent. The results there are more promising. For further information, see the MVHS Technical Report, "CoreModels Assessment" and the Center for Children and Technology "CoreModels Final Evaluation Report" available at http://mvhs1.mbhs.edu/mvhsproj/cm.html

Modeling Activities Development

MVHS leaders sought to investigate how modeling activity enactment might help students achieve Maryland Core Learning Goals. In order to consider a variety of science areas, student ability levels, and school contexts, leaders accepted over sixty teachers into the project. To provide a real opportunity for students to experience modeling activities, we asked each teacher to implement at least three different activities during each course. CoreModels took on many characteristics of an implementation project since we had to support a substantial number of teachers in fulfilling their primary requirement of enactment.

In addition to characteristics of an implementation project, CoreModels included many aspects of a multi-tiered teaching experiment as described by Lesh and Kelly (2000). First we needed to create, refine and test the classroom modeling activities. During 1997-1998 the CoreModels community, consisting of four teacher leaders and eight supporting teachers, put many student modeling packets through this process. The participating teachers who joined the project during the second summer also tested activities that were often revised based on their input.

The teaching experiments that Lesh and Kelly describe include three levels of investigators: students, teachers, and researchers. Students explore problems often developed by teachers. The authentic investigations of teachers involve creation of effective problems for students, the critique of such problems, design of assessments, and study of student work. Through such collaboration, teachers create shared constructs that inform their future work. Researchers study both student and teacher explorations. In one particular strand of work, the multi-tiered level of the CoreModels project has been very evident. MVHS students completed assessments that had been developed by teachers and researchers. Teachers examined the work of hundreds of students in scoring these assessments. This process was caught on videotape. MVHS researchers are studying the concepts exhibited by teachers in evaluating the student work.

MVHS leaders also sought to understand how peer support might help teachers in implementing modeling activities. Peer support can mean many things. The first section of this report reviewed the ways such support was more or less successful. But the aspect of the community as the medium of this support was not emphasized. Lesh and Kelly focus on the community as containing the shared constructs built up throughout a teaching experiment. Their explanation of how these constructs develop is consistent with and complimented by the information flow process adapted by Vandervert (2001) from Odum's energy flow principles. The information flows or common constructs may develop from the work of teachers in creating activities for students and so it is relevant to understanding how CoreModels functioned in developing modeling activities.

The diagram in Appendix II emphasizes the consistency between these ideas. Where references are neglected in the text below, the first term given is from Vandervert (2001), the second is from Lesh and Kelly (2000). The existence of the learning community involves the creation of *high quality information stores* (see 1, Appendix II) (Vandervert, 2001) or *community constructs* (Lesh & Kelly, 2000). This information *feeds forward* (2) or is *mutated* to create new draft materials. Such community understanding (1) includes higher level information that acts as a *control mechanism* (3) for the *selection* of draft materials. Shared constructs might include guidelines for creating teacher manuals and student packets, prototypes for comparison, and documents fleshing out benchmarks common themes and state learning goals in accordance with modeling skills. High level information includes access to the understanding of the community members such as content leaders, refiners, and implementers. Tested materials have survived “trial by ordeal” and/or “trial by jury” (Lesh & Kelly, 2000) and are propagated as part of the evolving community constructs (Lesh & Kelly, 2000). They feed back (4) to become part of the high quality information stores (Vandervert, 2001).

In order to supply special information needs of other organizations, implementation projects, or teachers not intimately involved in the TE/DE, source material from the information stores is preserved to be available to others (5). This material may be adapted as part of an implementation project. The project contributes useful information to the surrounding environmental system that helps maintain favorable conditions (6) (Vandervert, 2001), such as providing cooperating school systems with implementation data.

Within CoreModels, particular teachers were more interested in determining what would work in their own classrooms for themselves than in reaching consensus on common constructs. Teachers who joined the project during its last year may have had less opportunity to help form the store of community understanding and internalize common goals. Several other reasons exist for teachers to be considered primarily implementation oriented rather that teaching experiment oriented. Community development did not engage some teachers due to a multitude of other commitments or a classroom context that they considered too different from the general context. Other teachers were extreme individualists who most enjoyed reworking materials to fit their own ideas.

Implementation teachers may adapt materials on their own or with the help of a teacher leader. Unlike feed forward, there is no expectation that the adaptation will eventually effect the information stores. In fact, since the adapting teacher has not explicitly determined selection criteria in coordination with the community, there is no control mechanism other than not accepting the adapted material back into the information stores before the development of such criteria. Difficulty occurs when some propagation/preservation mechanism confuses adapted/non-controlled materials with tested materials. This is partially the problem of confusing teachers involved in the design/teaching experiment - who access and to some degree internalize the community constructs, with teachers involvement in the implementation project - who are interested in taking what works for them.

. Large-scale projects have tackled the issue of teachers modifying materials. Such implementation projects start with well-tested activities. But CoreModels content leaders continued to test and revise materials as others were adapting them.

> Scaling is a major thrust of educational reform initiatives; without broad impact in a large number of schools reforms run the risk of making no lasting change on the educational landscape. One of the clear lessons from our work is that curricular programs can not be ‘scaled’ in the sense of providing cookie-cutter curriculum that researchers feel must be implemented in a particular way in a wide variety of school settings. The resources and constraints that individual teachers encounter are divers and cannot all lead to the same enactment. We obviously want our curriculum to be adopted by as many teachers as possible, but we do not prescribe, or even anticipate that they will all enact it the same way. We build curricula that we fully expect will be adapted by teachers to their local classrooms. We think that this flexibility is one of the real strengths of our curricular programs. (Songer & McDonald, 2001).

MVHS teacher leaders took on a variety of roles within the teaching experiment and implementation project. The biology and physics content leaders were often more involved in developing the information stores and control mechanisms than in supporting implementation. In general, such leaders may pay too little attention to the consensus building process needed in forming the community's shared constructs that underlie further development and effective use. In the case of CoreModels, this was evident in leadership team discussions about the relative importance of process and product in developing materials. As leader of a large district, the central director focused on achieving implementation by helping teachers adapt materials to their own needs. Such implementation leaders may not be concerned with control mechanisms. But this leader also felt that having their work recognized by the community would reward adapting teachers. Since CoreModels had characteristics of both an implementation project and a teaching experiment, it would have been helpful if leaders had worked together to ensure that adapted materials were not confused with refined, tested materials. Creating additional control mechanisms to provide for selection of adapted materials would have been even more beneficial.

How did the materials development process result in peer support? Through the process itself, collaborating developers enjoyed support in fleshing out their ideas and talking through classroom problems and successes. Participating teachers who were engaged with the community had many opportunities to reflect with peers on the content and pedagogy of the modeling activities and how they might be improved. Their importance to the community was validated in the acceptance of their feedback. According to Friedman and Culp (2001),

> …teachers' discussions of their on-the-ground experiences with the curricula intersected with the developing thinking of the core curriculum team. These conversations were the key moments when the "big ideas" of systems thinking and modeling (especially about learning goals and optimal curricular and pedagogical approaches) combined with teachers' "real life" concerns and enthusiasms. The culture of this program framed both the "big ideas" and the "real life concerns" as being valid and important issues. Consequently, these conversations allowed teachers to explore, over time, how they might change their beliefs and practices in order to work more effectively with their students with these tools and curriculum.

Adapting teachers also had the opportunity to carefully consider their goals in classroom enactment and reflect on improvements working with a teacher leader or peer. Since the materials were developed within the project, they were themselves a focus for and embodiment of peer support. Pedagogical content knowledge from the developing teachers was build into the teacher guides. Teachers carried out activities at summer workshops where other teachers who had used them in the classroom (and often the developers – most successfully) were there to clarify and give examples of how difficulties could be overcome. During later summer sessions, peers worked together in enacting activities with workshop students.

In retrospect, it is clear that continual emphasis by the project director on the building up community constructs, emphasizing collaborative determination of guidelines for developing and implementing activities would have made the project even more successful. Such guidelines were developed by individuals and discussed by the leadership team. Articulating the character of the project as a multi-level teaching experiment would also have been helpful. Of course, explaining project goals is a continual process as teachers entered the project at different stages and grew to understand the project at different rates as described by the Concerns Based Adoption Model (CBAM) (Hord, et. al. 1987). For further information on the CoreModels activity development process, see "Working Paper: A Case Study of Materials Development Fostered by the MVHS CoreModels Project" available at http://mvhs1.mbhs.edu/mvhsproj/cm.html

Summary

. In considering the success of peer collaboration or support, we include an emphasis on the engagement of teachers in a community with evolving shared constructs. These results suggest that when teachers are supported by such a peer-driven professional development program they are able to integrate computer-based modeling within a range of curricular contexts to improve student understanding of some of the core scientific concepts underlying modeling as a scientific practice. Students' abilities to interpret visual representations of data seem more resistant to improvement, especially when measured over multiple content areas

According to Friedman and Culp (2001), "One conclusion that can be inferred from these findings is that central modeling concepts, such as the heuristic relationship of models to the physical world, seem to be relatively transferable concepts that can be elaborated across curricular content areas, while interpretation of visual representations of data remains, at least in this context, a more content-dependent skill that is not easily transferred from one content area to another. These findings demonstrate that CoreModels was successful in building teachers' understanding of and ability to teach about modeling, not only as a way to explore specific content areas but as a particular conceptual approach to the task of scientific inquiry."

Appendix I

References

Friedman W., & Culp, K. (2001). Evaluation of the CoreModels project: Final report. New York: Education Development Center/Center for Children & Technology.

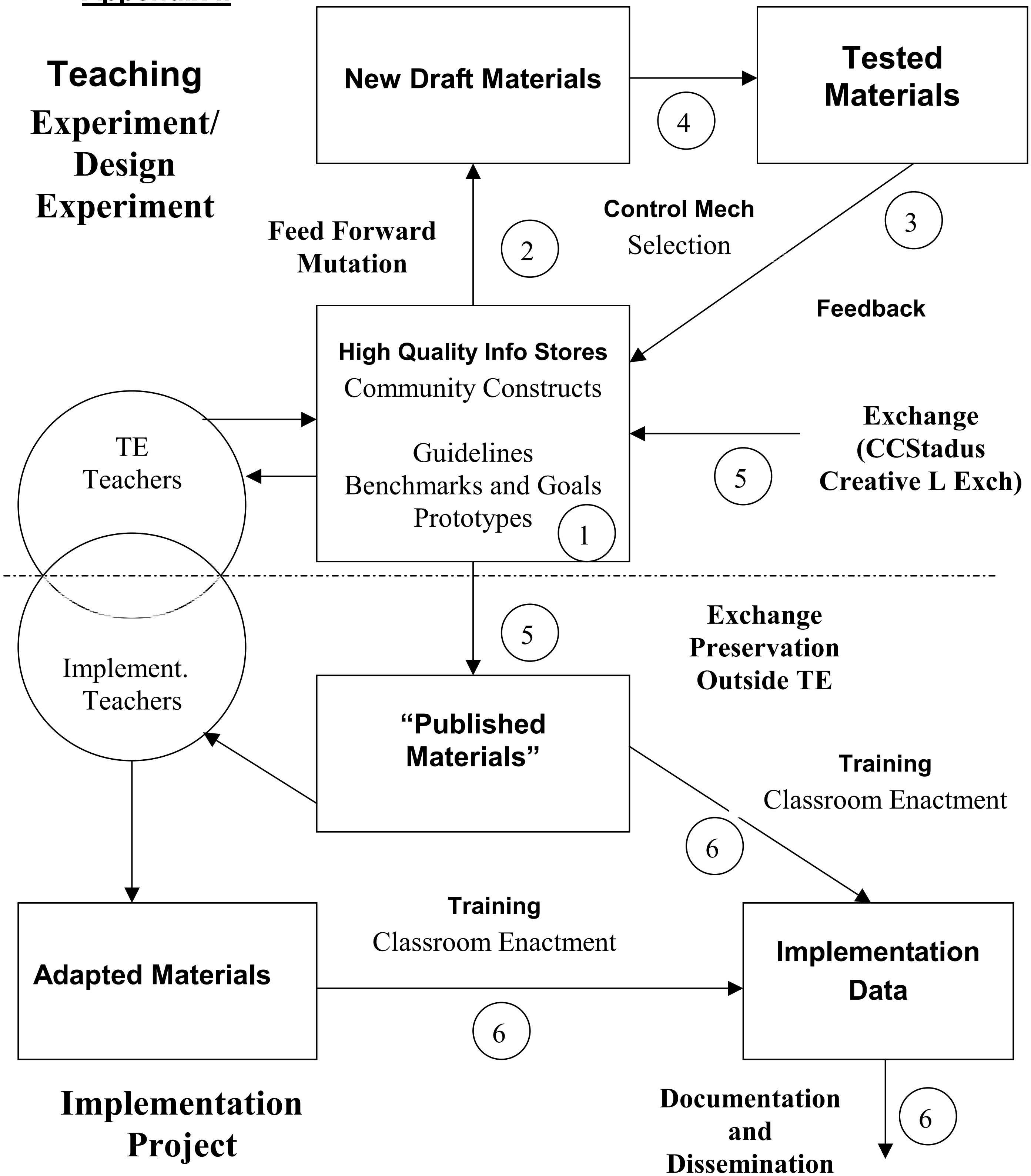
Hord, S., Rutherford, W., Huling-Austin, L., and Hall, G. (1987) Taking charge of change.Taking Charge of Change Shirley M. Hord, William L. Rutherford, Association for Supervision and Curriculum Development .

Lesh, R., & Kelly, A. (2000) Multitier teaching experiments. In Kelly, A., & Lesh, R. (Eds.) (2000) The Handbook of Research Design in Mathematics and Science Education. Hillsdale, NJ: Lawrence Erlbaum Associates

Songer, N., & McDonald, S. (2001) Smiling While Guiding Thirty Sixth Graders through Internet-Based Curricula when the Internet Is Down (and Other Lessons Learned with One Sky, Many Voices Projects) *ERIC UPDATE*, Volume 22, Issue 2. ERIC Clearinghouse on Information & Technology, Syracuse, NY.

Vandervert, L.R. (2001) A provacative view of how algorithms of the human brain will embed in cybereducation. In: L.R. Vandervert, L.V. Shavinina & R. A. Cornell (Eds.), *Cybereducation: the future of long-distance learning.* New York: Mary Ann Lievert, Inc.

Appendix II


Teaching
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