Complexities in Development of Educational Collaboratories as a Socio-Technical System: A Situated Study of the GK-12 EdGrid* Graduate Teaching Fellowship Program

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ABSTRACT

Little is known about the role of educational collaboratories as information systems for management of social (human) and technical (technology-related) factors in interdisciplinary contexts. Within a milieu of interdisciplinary issues in education, science, and technology, this paper takes a situated approach towards identification of complexities in the development of educational collaboratories in the GK-12 EdGrid Graduate Teaching Fellowship Program (GK-12 EdGrid Program). A situated approach calls for recognition of multiple context of use of innovative technologies in educational settings. The GK-12 EdGrid Program is a three-year National Science Foundation (NSF)-funded project to support University of Illinois graduate students in the sciences, mathematics, engineering, and technology (SMET) disciplines. Selected graduate students collaborate with campus faculty and participating K-12 teachers to integrate the use of computer-based modeling, scientific visualization, and informatics in science and mathematics education. Based on initial experiences at four participating high schools across Illinois, this paper draws attention towards a range of factors that are being negotiated for successful progress and implementation of GK-12 EdGrid Program's educational collaboratories during the project's first year. Such a research endeavor will be helpful in two ways: First, it will help to understand how the formation and evolution of an educational collaboratory determines achievement of particular short-term and long-term goals. This may lead to formulation of an agenda for their future application in other similar contexts. Second, such a strategy will provide a clue towards how development of an educational collaboratory takes place as an outcome of negotiation between multiplicity in perceptions, cultural practices, work ethics, and personal preferences. This will help to understand the multifaceted dynamics that take place in the development of educational collaboratories in interdisciplinary contexts.

Keywords: Collaboratories, Education, Science, Information Technology, Visualization, Socio-technical System, Situated Study.

INTRODUCTION

Collaboratories as a facilitation tool for "support requirements of cooperative work arrangements" [1] have attracted much attention in the context of Computer Supported Cooperative Work (CSCW) systems. Based on the concept of 'coordination mechanisms,' collaboratories have been applied in theoretical research and organizational practice towards the purpose of "coordinating cooperative activities in different work situations" [2]. In this role, an important aspect of collaboratories that has determined their effectiveness in different contexts has been their ability to negotiate cooperation and collaboration between various individuals across distances and disciplines [3]. This characteristic of a collaboratory goes beyond 'articulation work' to manage the distributed nature of cooperative dynamics in CSCW systems [4]. For interdisciplinary and cross-distance issues also entail a myriad range of human factors, including politics, policies, real work practices, and personal and cultural behavioral protocols that get negotiated when collaboratories are formed. This draws attention towards an inherent nature of collaboratories as a complex socio-technical system, which includes its manifold technical and behavioral components in all dimensions and their emerging interactions [5]. In such a context, a collaboratory can be understood as a multifaceted activity system that is shaped by emergent formal and informal interactions between people and the tools they use [6].

What makes collaboratories fascinating to study is their growth in terms of an "information ecology," that evolves as an outcome of interacting dynamics between people, practices, technologies, and values in a local setting [7]. In order for future collaboratories to take advantage of their constituents (both human and technological) for efficient utilization, there is a need to study them in terms of their constant redefinition and reconfiguration, as participants interact with each other and with associated technologies, and as participants' perceptions of their relationships within these frames of existence changes. Within such an evolution of collaboratories, it becomes apparent, to identify various issues and complexities that emerge in their development in individual projects and disciplines during different times.

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* *EdGrid is both the name for the infrastructure technologies and the name for the consortium of the National Center for Supercomputing Applications and its partner organizations called the EOT-PACI (Education, Outreach, and Training - Partnerships for Advanced Computational Infrastructure). For more details on the GK-12 EdGrid Graduate Teaching Fellowship Program, see http://www.ncsa.uiuc.edu/Divisions/eot/gk12/index.html*

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- First, it will contribute to an understanding of how the formation and evolution of a collaboratory determines achievement of particular short-term and long-term goals. This may lead to formulation of an agenda for their application in other similar contexts.

- Second, such a strategy will provide a clue towards how development of an educational collaboratory takes place as an outcome of negotiation between multiplicity in perceptions, cultural practices, work ethics, and personal preferences. This will help to understand the multifaceted dynamics that take place in the development of collaboratories in interdisciplinary contexts.

Within a milieu of interdisciplinary issues in education, science, and technology, this paper takes a situated approach towards identification of complexities in the development of educational collaboratories in the GK-12 EdGrid Graduate Teaching Fellowship Program (GK-12 EdGrid Program). A situated approach calls for recognition of multiple context of use of innovative technologies in educational settings. It acknowledges how a similar technology, shaped by its context of use, may acquire different meanings and associated social practices in different situations [8]. The GK-12 EdGrid Program is a three-year National Science Foundation (NSF)-funded project to support University of Illinois graduate students in the sciences, mathematics, engineering, and technology (SMET) disciplines. Selected graduate students collaborate with campus faculty and participating K-12 teachers to integrate the use of computer-based modeling, scientific visualization, and informatics in science and mathematics education. Based on initial experiences at four participating high schools across Illinois, this paper documents some complexities surrounding the development of educational collaboratories as a socio-technical system. It draws attention towards a range of factors that are being negotiated for successful progress and implementation of GK-12 EdGrid Program's educational collaboratories during the project's first year. This will shed light on the role of educational collaboratories as information systems for management of social (human) and technical (technology-related) factors in interdisciplinary contexts.

COLLABORATORIES IN SCIENCE AND EDUCATION

A National Research Council report first coined the term "collaboratory" in scientific research to fuse the idea of collaboration with that of a laboratory in its representation of a global computer network supporting a worldwide research community [9]. A collaboratory is a "center without walls, in which the nation's researchers can perform their research without regard to geographical location-interacting with colleagues, accessing instrumentation, sharing data and computational resource[s], and accessing information in digital libraries" [10]. The word was originally used to describe the Unidata Program, a pooled collection of data, resources, and experimental findings scientists shared to study atmospheric science phenomena [11]. Since then, it has been applied to various forms of collaborative efforts in business, research and development, and education, and consequently, a single definition of the term cannot account for all its multiple and complex dimensions [12]. For example, Ede and Lunsford identify collaborative efforts to include co-authorship in writing for diverse projects as the *Oxford English Dictionary*, the *Bible*, Short Title Catalogue, and elaborate computer programs [13]. In contrast, Robins [14] considers a collaboratory as a special kind of digital library, with salient advantages in terms of: a) its content, that is determined by the interests of the community; b) the less time needed in its development, owing to participants' collective efforts; and c) the distributed cost for its creation and maintenance. In the face of much diversity in its expressions, two disciplines where manifestation of a collaboratory draws attention are in the disciplines of science and education. Prospective bridges between science and education have particular significance, especially in today's age of "information explosion" and the subsequent transformations in our social life. For development of educational collaboratories embody potential solutions to solve contemporary problems posed by globalization, inadequate information retrieval and human management systems, as well as address the need for universal access and social equality to bridge the digital divide.

The origins of collaboratories in research and practice can be traced to science and scientific research [15]. Scholars have long realized the collaborative nature of science as reflected in its social processes and activities [16]. Study of authorship patterns and bibliometric analysis of scientific articles has shown that collaborative research in many disciplines has increased over the years [17]. The evolution of a scientific collaboratory has become an important social and organizational phenomenon [18], and recent research efforts have been directed towards an understanding of work processes in scientific collaboratories that contribute towards their development and successful implementation [19]. This has largely been owing to the realization that collaborative ventures are now a salient feature of change from Big Science to "Bigger Science" [20]. In this new scenario of space stations, global networks and extensive scientific databases, the role of information and communication technologies (ICT) in the development of a scientific collaboratory has been significant [21]. ICTs provide scientists opportunities to "exchange data, share computer power, and consult digital library resources, interacting across great distances as easily as if they were sharing a physical facility" [22]. The growth of collaborative scientific research has thus been significantly impacted by the design and evaluation of technology for cooperative intellectual teamwork. It has led to such "diverse products as computer hardware and software, advertising campaigns and jointly authored magazine articles" [23].

In recent years, collaborative initiatives in education, pedagogy, and training have also received considerable attention. Such developments have taken place as a reaction to assumptions guiding the operation of schools since the late nineteenth century that were based on the factory model and its reliance on centralization, standardization, hierarchical top-down management, a rigid sense of time, and accountability based on adherence to the system. That model is no longer valid in a post-industrial, knowledge-based society. Researchers both inside and outside of education have arrived at the same conclusions regarding a new model that offers the best hope for stimulating significant improvement in the ability of schools to achieve their objectives. This model requires schools to function as learning communities characterized by a shared mission, vision, and values; collective inquiry; collaborative teams; an orientation toward action and a willingness to experiment; commitment to continuous improvement; and a focus on results. These call for entrenchment of education in community to promote collaborative initiatives in teaching and learning that will help in democratic and impartial communication of collective thought, knowledge, and values to future generations [24].

Literacy and its relationship to learning in collaborative environments, to build community, is an "embodied, material act" that is closely entwined with the way it "shapes and is shaped by its technologies" [25]. Information technology (IT) in education, thus, has a real potential to nurture enriching experiences [26], develop collaborative environments for analysis and decision support [27], and build a learning community that acknowledges diverse elements via support of group identity and trust [28]. Educational technology has been identified as a particular kind of IT tool application in the context of teaching and learning. Educational technology can be differentiated into instructional technology that provides tools in the delivery of educational materials, and learning technology, which makes the experience of the students its central focus [29]. In its efforts towards promotion of collaborative learning, sharing, and exchange, an educational collaboratory includes both forms of educational technologies.

Advanced efforts have been made in the use of new emerging technologies to support collaborative teaching and learning within the past decade. These have included interdisciplinary partnerships that provide fulfillment to needs of learners in terms of Dewey's characterization of inquiry, communication, construction, and expression [30]. The Inquiry Page (http://www.inquiry.uiuc.edu) is an example of an online educational collaboratory for "curriculum development to support inquiry-based learning and teaching" that gives an opportunity to teacher, students, and interested others to develop guiding questions in the form of inquiry units that encompass activities of investigation, creation, discussion, and reflection [31]. Another online educational collaboratory that integrates the use of Internet in the classroom is network science-science curricula that utilize virtual scientific communities and shared dataset resources to support students' science learning. This NSF-funded project documented actual experiences of students and teachers as they participated in evaluation of online scientific curricula to make suggestions for improvements in content, usability, presentation, and aesthetics [32].

Recent improvements in computational and communication capabilities in SMET disciplines at colleges and universities are having a direct impact upon the K-12 community. Teaching and learning in K-12 classrooms have slowly started to change as schools take action towards adoption of SMET educational reforms [33]. The National Science Education Standards contain guidelines for K-12 teaching and learning reforms to develop combination of "hands-on" activities and "minds-on" experiences via inquiry in science education. Such an approach is grounded in practical investigation and help students "learn how to do science, learn about the nature of science, and learn science content" [34]. Emerging educational technologies are now identified as significant tools to engage students in meaningful classroom activities and direct student inquiry towards scientific learning [35].

The GK-12 EdGrid Program recognizes the importance of visualization technologies in science education to promote scientific inquiry and facilitate student learning [36]. The goal of the project is to develop educational collaboratories that may nurture growth of sustainable partnerships and support sharing and exchange in the use of computer-based modeling and scientific visualization in K-12 SMET education. It is envisioned such an agenda will also contribute towards national, regional, and local systematic change in teacher preparation as well as the development of K-12 content-rich curriculum materials and state-of-the-art SMET computational tools.

EDUCATIONAL COLLABORATORIES AS A SOCIO-TECHNICAL SYSTEM

Our understanding of educational collaboratories in the GK-12 EdGrid Program follows the "socio-technical nature of information infrastructure" based on their recognition "as an ongoing socio-technical negotiation" [37]. Such an agenda takes into consideration human factors and technological aspects, both of which have played significant roles in the development of collaborative applications for adopting educational technology in the SMET disciplines under the auspices of the GK-12 EdGrid Program. Recent research characterizes socio-technical systems in terms of a "complex structure involving the hybrid interaction of physical systems with agent (human) organization" [38]. Examples include hierarchical command organizations such as 911/Emergency Response Systems, utility infrastructures such as power grids, traffic and transportations systems, gas pipelines, telecommunication systems, electronic markets, and the Internet. Much work has been done on the Socio-Technical Systems Theory (STST) in the domain of information systems design and implementation [39]. In STST, the design of technologies are shaped, not only by users' abilities and needs, but, underlying drives and motivations to use technological tools are also given due recognition [40]. The evolving, contingent, and interwoven relationships established as an outcome of socio-technical systems have been considered critical to software engineering processes and "of late, an increasing body of attention has focused on the organisational, social and human factors that impact on all but the most simple system development projects" [41]. In order to highlight its socio-technical dimensions, the following discussion presents the institutions, human resources, and technology being used in GK-12 EdGrid Program's educational collaboratories.

Institutions

The National Center for Supercomputing Applications (NCSA) at UIUC is a significant partner organization in the GK-12 EdGrid Program and has agreed to contribute efforts and time of its staff and faculty, as well as, provide access to its computational and physical facilities. Administrators from four high schools in Illinois agreed to participate in the

GK-12 EdGrid Program and they selected teachers to work on the project based on voluntary participation. The four high schools represent a range of educational settings and give an excellent opportunity to study the situated nature of adoption and assimilation of scientific visualization and computer-based modeling in K-12 SMET disciplines.

In the GK-12 EdGrid Program, one participating public career high school (S1) is a cooperative undertaking, located in a suburban setting, that represents an alternative high school environment to juniors and seniors. Students come and study for half-a-day and take one/two courses per semester that provides them a practical focus of study. S1 provides students wide-ranging career education programs and vocational training in real work situations in areas like auto body repair, fire science, and cosmetology. The second school (S2) involved in the GK-12 EdGird Program has approximately 2325 students and is a four-year high school located in a suburban residential area. Over 86% of its graduates pursue a four-year college education. The third school (S3) participating in the GK-12 EdGrid Program is a four-year high school with approximately 1600 students that is located in an industrial town district in Midwestern Illinois. The fourth school (S4) in the GK-12 EdGrid Program is a four-year high school located in twin-cities with a large university campus within their midst.

Human Resources: The People Component
People involved in development of educational collaboratories in the GK-12 EdGrid Program are fellows (graduate students), mentors (faculty), high school teachers, high school students, school administrators, evaluators, NCSA staff and others. Four UIUC fellows were selected from SMET disciplines in the following areas: two students from biology, one from chemical biology, and one from library and information science. The selected fellows visited K-12 classrooms, approximately once in two weeks since fall 2001, to observe, offer assistance to the collaborating teachers, develop educational technologies and curriculum materials, and co-teach courses with the teachers. Broadly, the role of the graduate fellows in the GK-12 EdGrid Program was to a) function as intermediaries between K-12 teachers and scientists in SMET disciplines; b) become role models for future SMET professionals; c) contribute towards content knowledge building in principles of SMET disciplines; and d) cooperate in SMET instruction.

Mentors are UIUC faculty who voluntarily agreed to participate in the GK-12 EdGrid Program. Their role has been to advice fellows on a regular basis to discuss goals, activities, strategies, and developments at the assigned school. High school teachers participating in the project were highly devoted to teaching and learning. Their enthusiasm to develop educational collaboratories in the GK-12 EdGrid Program varied owing to extensive curriculum materials that needed to be covered in limited time and restrictions in educational standards that limited their creativity and flexibility. There were approximately 25-30 high school students in the classes where the fellows and teachers were working together to develop appropriate scientific visualization and computer-modeling tools. School administrators were instrumental in the process to establish agreements with NCSA staff and faculty in the initial stages of the project. An evaluation team of educators and selected graduate students was formed to evaluate collaborations between graduate fellows and K-12 teachers and students as well as study the impact of technology in the K-12 SMET educational settings.

Tools in Use: The Technology Component
The following discussion introduces the technological tools and associated ICTs that were used (or created) in the development of educational collaboratories in the four schools participating in the GK-12 EdGrid Program. Selection and use of the technological tools was based on the nature of the class and curricula, existing technological infrastructure at the participating school, and the expectations, teaching style, preferences, and skills of the teacher and fellow. The fellow at S1 assisted the teacher in a heating, ventilation, and air conditioning (HVAC) class. Based on class lessons, the fellow built a collection of computer-based tools, web resources, modified tutorials, and supplemental lessons in basic math, electronics, thermodynamics, fluid flow, and heat transfer. These were “tailor-made” and utilized for general classroom purposes and for individual students. Items in the collection were selected based on presence of scientific visualization elements. The fellow at S2 assisted the teacher in a biology class in the use of Biology Student WorkBench (BSWB), a bioinformatics tool developed by NCSA, that provides “access to biological databases and analysis tools through a web browser” (http://peptide.ncsa.uiuc.edu). The fellow helped develop and use existing BSWB “education enhancements” including tutorials, inquiry-based laboratories and resource materials that were applied to conduct open-ended investigations in molecular biology. The fellow at S3 assisted the teacher in three chemistry classes, developing strategies for integration and evaluation of molecular visualization curriculum materials within the classroom settings. The work focused on the use of ChemViz, a molecular visualization program developed by NCSA, that is designed to provide accessible tools to high school and undergraduate students and teachers to “enable inquiry and experimentation in atomic and molecular structures” (http://chemviz.ncsa.uiuc.edu). The fellow at S4 assisted in development of Biology Student WorkBench tutorials for use in the biology class. The idea was to modify existing online resources to suit the needs of individual teachers. Word processors, teleconferencing, electronic mail, and the Internet were the main technological-based tools used by the evaluation team to communicate with each other, conduct research, and develop appropriate internal formative and summative evaluation tools for the project. A website for the project was also developed as a centralized resource locator.

CHARACTERISTICS AND COMPLEXITIES

The central theme that has emerged in relation to the development of educational collaboratories in the GK-12 EdGrid Program has been the idea of multiplicity. Perceptions and expertise of various team members at the four participating schools as well as the evolving social dynamics in each of the context, determined different strategies for adoption of goals, plans of action, and the technological tools employed. Thus, it was not possible to identify a “cookie-cut” pattern for standardization that could be applied to the development of the four educational collaboratories in the different schools. The best approach in such a context has been a situated one, where we documented, studied, and analyzed the process in each situation on its own terms. Based on initial experiences in the project, the following discussion identifies some complexities encountered in the development of educational collaboratories in the GK-12 EdGrid Program. We also present some suggestions to keep in mind during future developments in the project.

Integration of resources (both human and technology-related) into the existing classroom curricula and fixed, time-bound schedules of the school's academic calendar were major issues to work with in the development of educational collaboratories in the GK-12 EdGrid Program. These resources included use of fellows' capabilities and time as well as the utilization of education technologies that were created or compiled for the project. Additionally, complying with curriculum standards and guidelines, even though sometimes they did not seem appropriate, was a tussle. Such concerns required constant negotiation and re-negotiation in terms of team members' time, commitment, and effort. These interactions emerged, directly in response to variations in individual contexts as the situation unfolded in the four schools, and were not something that could have been exactly planned in advance. An awareness of such issues owing to social and technical factors, about the undeterministic nature of educational collaboratories, will definitely help in preparation for unforeseen circumstances in future developments of the GK-12 EdGrid Program.

The nature of work in development of educational collaboratories in the GK-12 EdGrid Program has been very much in terms of "participatory action" [42]. This implies that team members working in the four schools, were themselves deciding what their goals were, and what course of action they had to take to achieve those goals. Sometimes such decision-making required intense discussions and patience. The teacher's experience and background helped in development of classroom curricula and time management. The fellows brought their discipline expertise, use of educational technologies, and knowledge of research strategies, onto the table. The understanding that different participants were coming in with different strengths and weaknesses was significant in the GK-12 EdGrid Program. This helped to realize, and plan, who and what resources could complement each other.

Interdisciplinary issues, played a specific role to shape the nature of interaction and determine specific outcomes in the GK-12 EdGrid Program. People from the sciences (biology and chemistry), mathematics, engineering, computer science, education, and library and information science were involved as participants in the project. This undoubtedly contributed towards varied visions that give a dynamic richness to the project. It also meant responding to a diversity in work styles, expectations, perceptions of which project goals were more important during particular moments, methodologies that were to be used, and basic world views. For example, participants from education were generally more concerned with conceptual and theoretical foundations. On the other hand, participants from the sciences were more concerned with the "nitty-gritty, nuts and bolts" of the project. Such variations in thought, sometimes led to unnecessary delays and deliberations, and obviously, there were also individual traits at play. What helped mediate such diversity in expression was a respect for each other's point of view, and the unspoken understanding that all concerned were sharing their views for the betterment of the project.

Adoption of a common vocabulary and a standardized language to denote different dimensions of the project was another area where professional and personal backgrounds shaped divergent perceptions. For example, in the initial project proposal, the word "evaluation" was used to denote the assessment of project goals in terms of effectiveness of visualization technologies in the K-12 classrooms and the study of social collaborations between teacher-fellow-mentor teams. Owing to loaded connotations of the term, fellows in two school teams felt concerned that either their individual work performance was going to be evaluated or the teacher and students would feel that way. It was suggested that the word "observer" or "facilitator" would serve just as well without causing undue tension. After much discussion on the issue, though finally the evaluation team leader decided to retain the word for formal purposes, yet one fellow still believed that the term was open for misinterpretation. The fellow went as far as to suggest not using the word in front of the particular high school teachers and students owing to the possibility of misperception. In order to acknowledge the fellow's reaction, it was decided to be extremely clear that the application of the word was not in the context of any particular school, but towards project goals as a whole. In that manner, we were able to negotiate the issue of multiple perceptions by adopting a strategy that did not have negative consequences on the project. This example shows, how participants immersed in different circumstantial positions in the project and performing different roles, had a variation in perception based on their contextual situations. An important understanding gained via this experience, was to keep in mind, how language had the potential to 'reflect' multiple meanings and specific political agendas that were open to interpretation based upon the contextual reality of the perceiver. It has led to a better understanding of the issues, and a need to develop a flexibility and openness to change, during subsequent stages of the project.

In the GK-12 EdGrid Program, both paper-based and computer-based tools were used synchronously and asynchronously. In all the four schools, fellows' devoted considerable effort and time to incorporate scientific visualization and computer-based modeling technologies within existing curriculum development and lesson plans. Fellows synchronized their strategies to use educational technologies with existing resources that were used by the teacher prior to the use of the computer-based tools in the classroom. Additionally, it is important to note that the development of educational collaboratories in the GK-12 EdGrid Program involved face-to-face and virtual components. In the context of the evaluation component of the project, it was essential to meet regularly face-to-face to establish communication, rapport, trust, common working expectations, and reach an agreement on adopted working protocols. Virtual interactions via such strategies like teleconferencing were not enough, especially during initial stages of the project.

An important lesson learnt in the development of educational collaboratories in the GK-12 EdGrid Program has been to give representation to all stakeholders involved in the educational process during every stage of project development (inclusive of project initiation and initial networking stage). For example, in two of the participating high schools, school administrators did not include teachers during the initial stages of project negotiation and project definition. During that time, discussions involved NCSA officials and school administrators, without consultation with the teachers. This had negative consequences for the fellows when they were sent into the classroom setting, since they had to spend considerable efforts to understand the points of view of the teachers and get them convinced of the project's validity. Such experiences call for due recognition of the teacher's role in educational reform efforts. K-12 schools are effective because of their teachers, not in spite of them. Even the most well conceived improvement programs fall flat if teachers lack the skills to implement them. In the GK-12 EdGrid Program, K-12 teachers and fellows are making attempts to bring principles of the learning community to life in their individual classrooms. Situated in the classroom-the critical focal point of the learning community-teachers are essential to any meaningful reform effort and are in the best position to have a positive impact on the lives of children. Lee Shulman [43] writes: "The teacher must remain the key…Debates over educational policy are moot if the primary agents of instruction are incapable of performing their functions well. No microcomputer will replace them, no television system will clone and distribute them, no scripted lessons will direct and control them, no voucher system will bypass them."

CONCLUSION

Both research and practice offer one inescapable, insightful conclusion to those considering an improvement initiative in education: change is difficult. After more than a decade of efforts to help schools reform, a weary Ted Sizer [44] admitted, "I was aware that it would be hard, but I was not aware of how hard it would be." The complexity and difficulty of change is a fact that cannot be overstated. Change is a complex and formidable task that is certain to be accompanied by pain and conflict. Many argue that pain is an essential element for initiating change and that the familiar status quo is always preferable to change until the traditional way of doing things results in considerable discomfort to those in the organization. We would argue that it takes a learning community to foster constant exploration of change as part of its culture rather than as a response to pain. But that does not mean discomfort either can or should be avoided. The change process is necessarily filled with uncertainty, anxiety, and problems-conditions that are certain to lead to conflict. In fact, the absence of problems and conflict, particularly in the early stages of changes, suggests that the initiatives are superficial rather than substantive. Michael Fullan [45] has emphasized, "Conflict is essential to any successful change effort." Initial experiences in the GK-12 EdGrid Program have shown that educational change is not simple and there are no easy answers. It is important to acknowledge challenges and complexities in different educational settings, especially in the context of changing technology use, in order to provide real solutions that are meaningful to the people involved.

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