Fostering Creativity in the Classroom:
A Case Study of a Multidisciplinary Design Project

Katherine Cennamo
Learning Sciences & Technologies
Virginia Tech
cennamo@vt.ed

Mitzi Vernon
Industrial Design
Virginia Tech
vernon@vt.edu

Abstract

Information technology includes many areas where design skills are required. The purpose of this investigation was to examine a multidisciplinary team charged with designing an immersive museum exhibit in order to develop a deeper understanding of the role of collaborative group processes in fostering and sustaining creativity. Using the factors identified in the literature on group creativity as a guide to data analysis, this research sought to determine the presence of those factors, as well as others, in student groups charged with developing a viable solution to the design problem. Although almost all of the characteristics of creative groups identified in the literature were present to some degree, the data indicated that four characteristics were especially powerful. Group diversity, a critical group norm, intrinsic motivation, and strong leadership emerged as prevalent factors within the case. These findings suggest that the literature on the characteristics of creative groups may have the potential to illuminate critical processes and environments for fostering creativity in design-related information technology (IT) courses.

Introduction

Creativity has traditionally been viewed as a solitary pursuit, however, it is widely recognized that creative acts are the not the result of the “lone genius”. Instead, current views of creativity acknowledge the role of collaboration in facilitating creativity and innovation. Recent work in the IT community has focused on the development of tools to support creativity. But beyond the availability of support tools, what can be done to establish a collaborative culture that facilitates and sustains creativity?

One culture in which creativity flourishes is the *studio*. There are music studios, dance studios, visual artist studios, industrial, interior and graphic design studios, architecture studios--all environments dedicated to creative acts. Further, these disciplines that value creativity situate part of their instruction in a studio setting.

The idea of teaching in a studio setting draws heavily from two historical models: the Ecole Des Beaux Arts in Paris, France (1819-1914) and the Bauhaus School of Design in Berlin, Germany (1919-1932) (Bender, 2005; Brown & Cruickshank, 2003). The studio method emphasizes learning by doing, where collaboration among students and faculty is a key factor in developing understanding (Reimer & Douglas, 2003). Students usually work in a design studio environment where they are provided with dedicated workspace. Studio classes typically meet three times a week for several-hour sessions, but students are encouraged to work in the studio rather than at home during off-hours. This establishes the studio as a work environment where they can share and interact with peers.

The specific teaching methods vary by program and university, but typically, students are presented with a design problem that is grounded in the realities of professional practice. Although periodic lectures on some aspect of the design problem may be delivered as needed, students are expected to work independently or in groups to learn various skills from each other. The focus of the studio is on the process of idea generation, critique, and evaluation. Faculty interactions stimulate student reflection on, and discovery of, their developing knowledge through project reviews and student questioning. At various points in the semester, students present their work to professional designers for critiques that complement and extend faculty reviews. In this way, students learn the process of design, from each other, from faculty, and from professionals in the field.

Several innovative Computer Science (CS) programs have incorporated the studio approach within their curricula (see, for example, Docherty, Sutton, Brereton, & Kaplan, 2001; Hundhausen & Brown, 2005; Ramakrishan, 2003; Reimer & Douglas, 2003; Spooner, 2000; Winograd, 2002). Although the logistics and procedures involved in the studio method have been well-documented for computing education (Reimer and Douglas, 2003), little is known about the instructional methods and processes that contribute to a studio experience that will develop and sustain creative outcomes. Thus, the purpose of this investigation was to examine a multidisciplinary studio-based course to discover factors that students believed fostered their creative work.

Context

The context of this investigation was a two-semester special studies course sequence offered through Industrial Design at a large research university. In this sequence of courses, a multidisciplinary student group was charged with designing a traveling science exhibit for middle schoolers as part of the planning phase of a NSF funded project. This exhibit, called "Phoebe's Field", teaches about physics fields such as electromagnetism. The project team was tasked to define the parameters and to design and test concepts as part of a submission for a second grant to the NSF to construct the exhibition that would visit several museums across the U.S. over a 4 year period.

The first course commenced in early September 2005 with a carefully chosen multidisciplinary design team comprised of 12 undergraduate and graduate students from industrial design, architecture, computer science, mechanical engineering, and instructional technology. In the Spring semester, the project continued and all existing student team members were invited to participate. While some of the existing team members chose to leave, 7 out of the original 12 continued with the project, and two additional students joined the team for the Spring semester. It is important to note that the studio environment for this project was never about the work of individuals, but indeed the work of diverse voices coming together to a 'round table.' Further, there was something at stake beyond a hypothetical assignment, which made it requisite to everyone to work cooperatively.

Students were required to work with investigators on the grant team as well as designers, engineers, and educators from across the country. All in all, the students were responsible to ten project advisors, five consultants, one contractor, and four Co-Principal Investigators that included experts in educational technology for children, science exhibition design, and mechanical and electrical engineering, as well as architecture and education faculty. Students and faculty worked in the context of a design studio environment through most of the project year; however, the course was conducted without an allocated studio space and extended class hours, two infrastructural aspects often considered definitive of studio education in architecture and other design programs today. Advisors joined the team on four separate occasions to see and discuss progress. The emphasis of the courses was on the cycle of ideation, presentation, and critique, with reviews focusing on creative problem solving and the quality of concept expression. Course evaluations were based on graphic and video portfolios of exhibit events. Deliverables included two presentations to members of the advisory board on campus, a presentation to the advisory board at the Center for Children and Technology in New York City, a complex exhibition proposal in book form, and a multimedia exhibit on campus for the assigned NSF program officer. (See Project Website: http://www.phoebesfield.org/)

<u>Role of Researcher</u>

As an educational advisor on the project, I did not begin this project with the intent of collecting data. However, early in the project, I became impressed with the students' work and their resilience, drive, and motivation; thus, I began my investigation of the case to document characteristics of the group, task, and process that might inform future teaching and research endeavors.

As I observed the students' initial meeting with the advisors in October, I was struck by the quality and originality of the students' work. The presentations were well-researched, and many hours had been put into the visual and conceptual presentations. However, the advisors proceeded to critique the work to the extent that few of the original ideas were retained. Following the advisors' critiques, I was even more impressed at the way the students simply resumed work re-conceptualizing the project. A similar thing happened at the December meeting, though in many ways, it was more severe. The group had coalesced around one exhibit idea, and each student team was responsible for one aspect of the exhibit. Students presented to a large group of advisors and visitors that included many who had not attended the previous meetings. Once again, key ideas that represented hours and hours of work were discarded based on an advisor's comment. As the year progressed, more and more people became interested in the collaborative processes used within this very productive multidisciplinary design group. Those of us who have observed this process all along have remained fascinated by it.

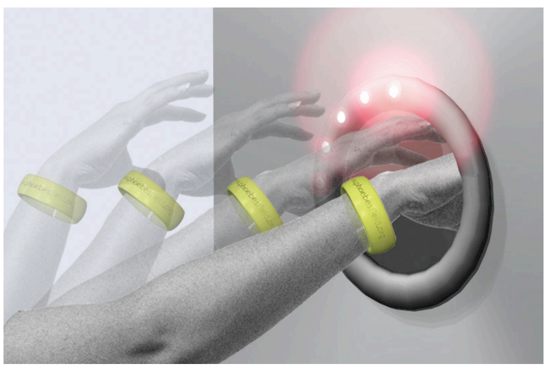

Figure 1: Sample student product

Figure 2: Design team meeting

Data Collection and Analysis

The primary data were collected through open-ended surveys and a focus-group interview. Survey data were collected through two anonymous online questionnaires administered by one of the students in the class. Questionnaires were completed by the student team in February and by all project participants (student teams, advisors, PIs) in April. In early June, all of the students and the course instructor participated in a focus group interview of one and one-half hours in length. During the focus group, students were asked to discuss the process through which they developed the museum exhibit design. The focus group data were recorded and the data transcribed for analysis.

Additional data were used to triangulate the primary data set. Field notes were collected during observations on three occasions in the fall semester and on one occasion in the spring semester. I attended the students' presentations to advisors and follow-up discussions in October, presented educational literature that could serve to guide the design in November, observed student presentations to the advisor team and follow-up discussions in December, and attended the presentation to the NSF program officer in May. Additional observations occurred through informal conversations with the students during breaks in the formal presentations. Other secondary data included written summaries of the project prepared for various reasons including journal articles, conference and grant proposals, case study competitions, and the project book.

Data analysis began with a review of the primary data set to look for characteristics identified in the literature as contributing to creative group outcomes. Using the pattern matching technique described by Yin (2003), factors that had emerged from the literature on creative groups were used to establish an initial set of coding categories (see Table 1). During a practice session, the primary researcher and an independent reviewer both searched the data to identify instances of each characteristic. Differences in coding were discussed until both reviewers agreed upon the meaning of each coding category. Following this orientation to establish shared meaning for each coding category, the independent reviewer coded the remaining data, while remaining open to data that did not conform to the pre-established categories.

Data that did not fit within established categories were further reviewed and clustered into additional categories using a constant comparative method (Merriam, 1998). This method requires an iterative process of identifying major and recurring themes in the data, developing categories for these themes, working with and coding the data to reveal representations of the identified categories, and synthesizing categorized data within a larger context, which identifies essential relationships and processes. Additional coding categories were necessary to account for data that did not fit into the pre-established categories derived from the literature.

The coded data were reviewed by the primary researcher to determine agreement or disagreement with the way the data were coded; however, no discrepancies were found. Secondary data sets were reviewed to provide additional insights into the context of the case. Data were organized into a table that noted the data that supported each coding category.

Following this initial coding, the primary researcher reviewed the coded data to determine the most salient features of the case and to gain insight on the group characteristics and processes that contributed to the success of this inter-disciplinary design effort. The data were further analyzed using the constant comparative method (Merriam, 1998) to develop coding categories that illuminated the "story" that emerged in the data set. The course professor and student project-manager reviewed all the findings from the data analyses as a means of member checking the results of the analysis.

Findings

Students, faculty, and advisors alike viewed the project as a success. When asked to identify achievements, one advisor commented, "The product as it stands now is a huge achievement - in its conceptual and scientific considerations and as an incredible illustration of the potential that exists by working across contexts and within different groups of people (students and professionals, designers and educators, etc.)" (#14, Q, W, 9) [1].

As illustrated in Table 1, many of the characteristics identified in the literature as conducive to creative work groups were present in the course.

---

[1] Keys to coding

- #8, Q, W, 6 - response of participant 8, on the questionnaire to the whole group, question number 6.
- #10, Q, S, 7 -response of participant 10, on the questionnaire to the students, question number 7.
- Lynn, FGT, p. 30 - Lynn's (pseudonyms used) comment, focus group transcript, page 30.
- AIA, p. 16 - page 16 of project summary prepared by the student project manager for the American Institute of Architects case study competition.

Table 1: Characteristics of creative work groups and supporting evidence

Characteristics	Supporting quotes from data
Membership	
Diversity of knowledge and expertise	The different disciplines not only brought more opinions and different ideas because of their different lives but they have knowledge of subjects that other did not.- #10, Q, S, 7
Newcomers alter knowledge	(In reference to the 2 new class members in the spring).. Having fresh voices on it, that's going to come to a place, they are getting places that we would have never, even stopping and starting, stopping and starting however we decided to do it, we had never come to that point. - Carl, FGT, p. 23.
Intrinsic motivation	You get projects where you design some thing for this imaginary purpose, and then we have you know well we wanna help middle school aged girls learn about science and get them interested and it's like, "This is *really* cool." This is worthwhile and if this actually happened and we did a good job and you might get more kids interested in science, you know. It's something that's, you know, you can actually grab a hold of it and like make it important to yourself. -Jay, FGT, p. 12.
Group processes	
Accepting of diverse opinions	Allowing for and considering input from all team members (there is no wrong answer). - #1, Q, S, 7.
Supportive climate- where group members help train each other	I think you guys [the ID students] were patient too. … We kind of had to be coached. Like when Janice sat with Karen and I, she was like "Look, this is how it goes." {laughter!} "You do this because you are asked to do this and you know let it go." And I think, you know, among the group there were definitely coaches that were kind of like "In ID, this is kind of how it is." - Joy FGT, p. 25.
Trust	It goes back to that, you know, a lot of that trust issue that every single one of us would probably agree that we just felt that the group was capable of this. We trusted in the project and everybody's capabilities.- Carl, FGT, p. 18.
Openness	Open ideation and discussion is definitely a must have. Being able to freely voice opinions and bounce ideas around was extremely generative. -# 4, Q, S, 8.
Reflect on group processes	It ceased being a project, and it started being a story of you know a year and not just a year in all of our lives, but a year with that project and a year with this sort of developing, bubbling, changing constantly being different. -Carl, FGT, p. 17.
Critical group norm	From a design perspective, critique is a delicate proposition for students outside of the typical design studio culture. So, the distillation of ideas could seem abrupt to some students. However, I never witnessed any serious withdrawal of students as we needed to narrow from many ideas to a few.-#12, Q, S, 7.
Avoidance of premature consensus	The fact that so many ideas were pursued and improved only to be replaced by another idea is very good in my opinion. It shows that the group and the design process is broader than simply finding a solution but dedicated to finding the best solution. I feel lucky to be a part of the design even though it is in the later part of the process. - #6, Q, S, 9.
Creativity valued	This design process is much different than what I am used to. There is a lot more free thinking allowed and creation of new ideas.-#8, Q, S, 6.
Group contexts/ environment	
Freedom/ Autonomy	The class was more "freestyle" than others. It evolved as the semester proceeded. Almost everyone had an equal say in how things were done or had to be done (with the exception of certain executive decisions that had to be taken). Though it seemed a little chaotic at times, I think it was a really good learning experience.-#7, Q, S, 6.
Supervisory encouragement	I've never received so much encouragement about anything I've done, like, and so much compliments.- Will, FGT, p. 14.

Adequate time to generate/contribute a variety of ideas	Even though it was outside of my expectations, I really thought the long process to develop many concepts and really think about why we were designing this exhibit was crucial to the overall design. What I thought should have been a quick design solution, turned out to be a detailed, thought thru idea. And I think that was a positive aspect to making the project a success.- #9, Q, S, 8.

Although almost all of the characteristics of creative groups identified in the literature were present to some degree in the class structure, the data indicated that four characteristics were especially powerful. Group diversity, a critical group norm, intrinsic motivation, and strong leadership emerged as prevalent factors within case.

Diversity of knowledge and expertise was of primary importance. When asked to describe one or more experiences interacting with the team members in terms of the challenges as well as the benefits, one student responded "The different disciplines not only brought more opinions and different ideas because of their different lives but they have knowledge of subjects that others did not." (#10, Q, S, 7).

At the same time, *navigating this diversity was not always smooth*. One student commented, "There is definitely a disconnect between the scientists and the designers and those involved with social or human development. Sometimes it seemed as though people just weren't getting each other and the same idea was communicated over and over again."(#1, Q, W, 7).

Part of this disconnect was due to *difficulty communicating* between those in architecture and industrial design and other disciplines. One design student commented, "When I was working with team members who's area is in computers and engineering, we did not always speak the same language. For example, one team member and I talked around and around for some time about desired technology vs. design practicality without resolution. Some of the time I could see that there were non-design folks who didn't get some of the design terminology being thrown around."(#1, Q, S, 7).

Of particular note were the differences in design cultures among the group members. This disconnect was felt by both the industrial design students and the students from other design disciplines. On one hand, there were differences in aspects of the problem to which the students attended. When asked to describe the process and method used in the class, one engineering student commented, "This design process is much different than what I am used to. There is a lot more free thinking allowed and creation of new ideas. With my engineering courses things were very concrete and variation from the norm was never usually looked upon very well. If something met the needs of the problem and did it inexpensively it was considered well done. There was very little room for creativity." (#8, Q, S, 6). A design student commented, "For the interactive theater, I was grouped with two engineers. While they had a lot to offer on the project, it was a challenge to, see, work together and collaborate--the different angles we were coming from. I was thinking design and aesthetics, while they were thinking technical and details on the science aspect…" (#9, Q, S, 7).

Many times, the differences were due to deeply embedded assumptions of the students' various design cultures. One design student commented, "At first it was challenging working with one individual that does not come from a design background. … if he had an idea that other members of the group did not like, he thought that must be because we did not understand him, and he would continue explaining the same idea over and over again. People with design backgrounds are less attached to their ideas, and are okay with it when ideas get thrown out." (#3, Q, S, 7).

As alluded to in this quote, many of these differences centered around the way industrial design students are taught to view the idea generation and selection process. One student explained it succinctly during the focus group: "I think that designers learn to let things go as part of their education and the whole process. I always wondered how people from other disciplines would deal with that, because, you know, we are used to just throwing ideas out there and you know you have to. Especially a professional world, you are selling them. But you know they might not work. You have to believe in them because you want them to work. If they don't, well, if they don't make it, they don't make it. You let it go." (Lynn, FGT, p. 30). Another student commented "…the second I put something out there it's not mine … And that's how you have to give your ideas vitality by letting them be themselves….in the fall you could definitely see we had people in the group that weren't willing to just cut it and let it go." (Carl, FGT, p. 25)

The culture of criticism was not familiar to all students. When referring to the challenges of working in multidisciplinary groups, one design student commented, "They also didn't seem to get the process of spending lots of time coming up with design ideas and going through open forum critiques only to have the ideas thrown out and having to start from scratch again." (#1, Q, S, 7).

The design students spoke to the *importance of critique and discarding idea*s. Students who were familiar with the culture discussed why they were not bothered by criticism (FGT, p. 33).

Jay: The way I look with my projects in studio when (the professor) tears apart my work. It's like, when (the professor) actually deigns to look down on my crappy little work and go "Hmm, that's interesting enough for me to form a thought and give you feedback." {laughter!} It's like, "Yes!" She's saying something negative, but yes that gives me something to build on.

Mona: That's how I am. I'm like, well at least she's taking the time to tell me what I should do.

Carl: It's fired her up in some way.

Those who were familiar with the culture took aside those who were not and let them know how it was done. As one student from education noted in the focus group, "… We had no idea. We kind of had to be coached. Like when Janice sat with Karen and I, she was like 'Look, this is how it goes.' {laughter!} 'You do this because you are asked to do this and you know let it go.' And I think, you know, among the group there were definitely coaches that were kind of like 'In ID, this is kind of how it is.'" (Joy, FGT, p. 25)

However, students *repeatedly acknowledged the benefits of working with other disciplines, despite differences in perspectives and cultures.* This was true for both the students from "non-design" backgrounds, and those who were industrial design students. One design student, commented, "The challenges of working in multidisciplinary teams is that other disciplines follow a vastly different design process than what I have been taught (fail early to reach the better design and don't get too attached to any one idea because it can always be done better). Although this was at times frustrating, the expertise members of the team from other disciplines provided broadened my scope of understanding and their knowledge base allowed for them to generate ideas that I would not have." (#4, Q, S, 7). A non-design student commented, "Working with other disciplines provided me with a broader way of thinking, and resulted in a much larger pool of ideas to pick from…The challenges mostly arose when it became apparent that those in the majors who focused on creativity, focused very little on whether or not the final idea agreed with the physics behind it. In a way, having both types of majors present provided for a sort of check on each other." (#11, Q, S, 7).

Eventually, trust was built up, and everyone became comfortable with the culture and each other. When asked about significant breakthroughs, one student commented, "I think once the teams started thinking like other team members thought, and really started listening to everyone's input, things started to take off. The engineers were beginning to think like designers and designers understood more of the engineer's or computer science side." (#10, Q,S,10).

Students *began to work as a team* rather than individuals. In the focus group, one student commented "…there's not too much about this that's individual. It's not really about, you know, doing well within the group, you know, being better than anyone. It's about the group doing better, and then because the motivation isn't really, you know, in the grade or whatever. It's in the group doing well in this thing that we have all worked so hard on, actually working at some level that all, you know, I should say most aspects of competition disappear." (Dan, FGT, p. 22).

The unity of thought was evident in the focus group, where students were completing each other's sentences. This unity of thought is illustrated in the following passage (FGT, p. 22).

Carl: I don't think there is, you would be hard pressed, even if there were little pieces of things, oh, this is this person's idea, it's been re-thought=

Joy: Massaged and polished

Jay: Worked over so much

Carl: = that ownership is dissolved.

They also learned to trust and appreciate each other's strengths and weaknesses, as illustrated in the following passage: "…at the same time we were comfortable with, say, if I have something to ask about layout, I definitely need to go to Carl. Or if I have a science question, Aaron was there." (Jay, FGT, p. 9).

A critical component of pulling together as a group came from the "deadlines" that resulted from the presentations to the advisory board. "You know we had these big presentations …You start to develop that trust, not just in what you are capable of, but as the group moves through these things, you trust that, you know, everything is going to get done and everything is going to get done really well." (Carl, FGT, p. 2). They spoke of their "panic calendar" where they were meeting constantly in order to meet the deadlines (FGT, p. 13).

Carl: "It's where we went from meeting every two weeks to meeting every two hours. {laughter!}

Will: So, we never really left the meeting. {laughter!} It was just like this table in the studio.

Carl: It was almost like a continual meeting with people kind of coming in and going out, coming in and going out. {laughter!} (several speaking at once)

Molly: Break for a shower.

Will: Break for Starbucks.

Mitzi: It really was that way the last two weeks before New York. I mean we were either meeting in the conference room or meeting downstairs in the studio.

Students looked at these presentations as "high stakes", yet repeatedly spoke of it being an "honor" and a "privilege" to work on the project. In the focus group, one design student commented, " We got to present it in front of a board of professionals. What other student gets to do that? We had the possibility of what we designed maybe someday making it in some form into reality and no students get to do that." (Dan, FGT, p. 16).

As alluded to in the previous quote, this culture existed simultaneously with a *strong degree of intrinsic motivation*. In the focus group, one student explained, "There's nothing really academic at all about the motivation. The motivation is that this is a real thing and what it takes at that point is somebody going out on a limb and trusting all this money to your work as a student-- free to say, 'Wait a minute there's something really important about this,' and that's not something that can really be, ah, faked and it's obvious to everyone here that this is an enormous privilege, you know, and when it becomes an enormous privilege all these other things fall into place because we care ..." (Dan, FGT, p. 16)

Students repeatedly talked about the fact that it was "real" rather than an academic exercise. They also viewed it as a opportunity to work on something that could be of potential benefit to future generations. One student explained that " … The fact that it is a very real and legitimate project is a huge motivation to do the very best work on it. I liked both that it was something unique and that it was something important and might someday be a reality." (#6,Q, S, 5). Another student succinctly stated his expectations of the project in the questionnaire. "I hope to take my children to it and say daddy did that, that is, when I have children." (#12, Q, W, 16).

This project was also unique in that the c*ourse professor was heavily invested in the success of the project*. In a summary of the project, one student stated that "Mitzi expected a lot from the students but gave even more. Her impassioned and charismatic leadership balanced by high expectations and strong criticism brought the team to a new level of performance from the previous semester."(AIA, p. 32). In the focus group, another student commented, "One thing was that Mitzi was with us at every step-- not like other classes where you meet with them once a month to do their progress reports … When we were not sleeping, Mitzi was there not sleeping along with us. {laughter!} She was there through all of us at the same time. She was there for every meeting." (Aaron, FGT, p. 18).

Discussion

In our investigation of the process through which this multidisciplinary group of students, faculty, and professionals collaborated to design an innovative immersive science museum exhibit, our results were consistent with literature that delineates factors shown to facilitate creative outcomes, primarily in studies of professional work groups. Consistent with that body of literature, the diversity of participants influenced creative outcomes within the group (Nijstad & Paulus, 2003). Stasser and Birchmeier (2003) indicated that it is the diversity of information that is important. As found in other research (Chio & Thompson, 2005; Katz, 1982), the effects of newcomers on the group process was generally positive in that it increased the information diversity and compelled the existing students to reconsider some of their design assumptions.

In addition, a diversity of problem solving strategies was exhibited in the composition of the group (Kurtzberg, 2005). While some group members were initially more comfortable with high-structured, process-oriented approaches and others were more comfortable with unstructured, broad, idea-generation approaches, Kurtzberg found that groups that contain a mix of problem-solving types generate more creative outcomes than those comprised of members who are homogenous.

Within the literature, a critical, yet open and supportive group norm has been shown repeatedly to facilitate creative outcomes (Tjosvold, 1998). Although it is important that the groups exhibit openness to multiple ideas during the idea generation phase, criticism that maintains high-standards is valuable during the idea selection phase (Hooker, Nakamura, & Csikszentmihalyi, 2003). A "somewhat critical but open climate, in which new ideas are valued, but in which there is no excessive consensus seeking, appears to be most beneficial for creative performance" (Nijstad & Paulus, 2003, p. 330). Hennessey (2003) proposed that groups that are open, yet also have a degree of autonomy and control, facilitate intrinsic motivation where the participants perform the task for it's own value, rather than for some external reward. Further, the literature has show that creativity is enhanced by a supportive climate where group members help and train each other (Hooker, Nakamura, & Csikszentmihalyi, 2003). Other group climate factors found to be important in both the literature and our findings include interpersonal trust (West, 2003), the perception by members that their contributions were valued (Stasser & Birchmeier, 2003), and challenging tasks (Amabile, Conti, Coon, Lazenby, & Herron, 1996).

In addition, West (2003) argued that the role of the leader is critically important, though often overlooked. From the data, it was obvious that the transformational leadership style of the course professor contributed to a group process characterized by trust, high standards, and openness, as well as a critical group norm. "Transformational leaders influence group members by encouraging them to transform their views of themselves and their work. They rely on charisma and the ability to conjure inspiring visions of the future….. Such leaders use emotional or ideological appeals to change the behavior of the group, moving them from self-interest in work values to consideration of the whole group and organization" (West, 2003, p. 266).

Generalizations

So what can we derive from this case study of an multidisciplinary group's experience in designing a museum exhibit that can be of use in developing an educational environment to foster creativity in future information technology professionals?

It's obvious that the project benefited from the diversity of the group membership as well as a design culture that values generating, critiquing, and discarding ideas within the context of a real project with perceived benefits to society. High stakes deadlines such as presentations to a professional advisory group contributed to the standards that the students set for themselves. Students felt they were treated professionally and rose to the occasion.

Although we will not always have access to projects with perceived benefits to society, there are other lessons learned from this case that we can incorporate into our classes more easily. We can attempt complex projects that extend across multiple semesters, recognizing that some students may leave the project and others may join, but that changes in group composition can be beneficial. We can require students to present to professionals from various fields and advisory groups to raise the stakes. We can work to establish social norms that value generating and discarding ideas freely. We can prepare our students to welcome critiques as valuable to the idea selection process as opposed to seeking consensus. We can always treat students with respect and invest resources in them. And as professors, we can fully participate as members of the design team.

Conclusions

Information technology includes many areas where design skills are required: human-computer interaction design, algorithm design, software engineering design, network design, and database design, just to name a few. In other research, investigators found that several of the characteristics we identified in our student group influenced innovative outcomes in the work of a Requirements Engineering class in which student groups developed systems specifications for clients (Dallman, Nguyen, Lamp, & Cybulski, 2005). These findings suggest that the literature on the characteristics of creative groups may have the potential to illuminate critical processes and environments for fostering creativity in design-related information technology courses.

The case study reported herein is part of a larger body of work that seeks to merge models of individual creativity with what is known about establishing and maintaining creative work groups for the expressed purpose of creating educational guidelines for developing critical and creative thinking skills in the future workforce. Additional research will seek to identify class activities and group member behaviors that contribute to the development of creative outcomes to design problems within the context of a studio-based class. We are currently engaged in a 3-year collaborative research and education project involving three universities (National Science Foundation Award # IIS-0725290). Through an investigation of the design process used within an interdisciplinary studio-based project and Human Computer Interaction courses that incorporate a modified studio method, we plan to derive principles that can be applied to the education of future computer science professionals. As Rowland (1993) pointed out, there are many similarities among design disciplines and indeed, we have much to gain by examining techniques that are effective in the preparation of other designers in order to strengthen the preparation of future information technology professionals.

***Author notes*:** This work was supported by Grant No. ESI-0442469 from the National Science Foundation. Any opinions, findings and conclusions expressed in this article are those of the authors and do not necessarily reflect the views of the National Science Foundation. Other project team members who contributed to the data collection and analysis include Leigh Lalley and Phyllis Newbill.

References Cited

Amabile, T. M., Conti, R., Coon, H. Lazenby, J. & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal, 39*, 1154-1184.

Bender, D. (2005). Developing a collaborative multidisciplinary online design course. *The Journal of Educators Online*, *2*(2), 1-12.

Brown, S., & Cruickshank, I. (2003). The virtual studio. *The International Journal of Art & Design Education, 22* (3), 281-288.

Choi, H-S., & Thompson, L. (2005). Old wine in a new bottle: Impact of membership change on group creativity. *Organizational Behavior and Human Decision Processes, 98*, 121-132.

Dallman, S., Nguyen, L., Lamp, J. & Cybulski, J. (2005). Contextual factors which influence creativity in Requirements Engineering. *Proceedings of 13th European Conference on Information Systems, ECIS* Regensburg, Germany.

Docherty, M., Sutton, P., Brereton, M. & Kaplan, S. (2001). An innovative design and studio-based CS degree. *ACM SIGCSE Bulletin, Proceedings of the 32nd SIGCSE Technical Symposium on Computer Science Education*, *33(1),* 233-237.

Hennessey, B. A. (2003). Is the social psychology of creativity really social? Moving beyond a focus on the individual. In P. B. Paulus & B. A. Nijstad (Eds.), *Group Creativity: Innovation Through Collaboration*. New York: Oxford.

Hooker, C., Nakamura, J., & Csikszentmihalyi, M. (2003). The group as mentor: Social capital and the systems model of creativity. In P. B. Paulus & B. A. Nijstad (Eds.), *Group Creativity: Innovation Through Collaboration*. New York: Oxford.

Hundhausen, C.D. & Brown, J. L. (2005) Personalizing and discussing algorithms within CS1 studio experiences: an observational study, *Proceedings of the 2005 International Workshop on Computing Education Research*, 45-56. New York: ACM.

Katz, R. (1982). The effects of group longevity on project communication and performance. *Administrative Science Quarterly, 27*, 81-104.

Kurtzberg, T. R. (2005). Feeling creative, being creative: An empirical study of diversity and creativity in teams. *Creativity Research Journal, 17(*1), 51-65.

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco: Jossey-Bass.

Nijstad, B. A. & Paulus, P. B. (2003). Group creativity: Common themes and future directions. In P. B. Paulus & B. A. Nijstad (Eds.), *Group Creativity: Innovation Through Collaboration*. New York: Oxford.

Ramakrishan, S. (2003). MUSE studio lab and innovative software engineering capstone project experience. *ACM SIGCSE Bulletin, Proceedings of the 8th Annual Conference on Innovation and Technology in Computer Science Education ITiCSE '03*, 35(3), 21-25. New York: ACM.

Reimer, Y. J. and Douglas, S.A. (2003). Teaching HCI design with the studio approach. *Computer Science Education Journal, 13(3),* 191-205.

Schon, D. A. (1983). *The reflective practitioner.* New York: Basic Books.

Stasser, G. & Birchmeier, Z. (2003). Group creativity and collective choice. In P. B. Paulus & B. A. Nijstad (Eds.), *Group Creativity: Innovation Through Collaboration*. New York: Oxford.

Tjosvold, D. (1998) Co-operative and competitive goal approaches to conflict: Accomplishments and challenges. *Applied Psychology: An International Review, 47*, 285-342.

West, M. A. (2003). Innovation implementation in work teams. In P. B. Paulus & B. A. Nijstad (Eds.), *Group Creativity: Innovation Through Collaboration*. New York: Oxford.

Winograd, T. (2002). Website for CS 247A: http://www.stanford.edu/class/cs247a/.

Yin, R. K. (2003). *Case study research design and methods.* Thousand Oaks: Sage.