Inspiration Brief 1

Concept Paper: Defining Inspiration, the Inspiration Challenge, and the Informal Event

Debbie Denise Reese
Beaumie Kim
Deniz Palak
Jeffrey Smith
Bruce Howard

NASA-sponsored Classroom of the Future

Center for Educational Technologies®
Wheeling Jesuit University

COTF/IB1/6-2005

About the NASA-Sponsored Classroom of the Future

The NASA-sponsored Classroom of the Future helps to bridge the gap between America's classrooms and the expertise of NASA scientists, who have advanced the frontiers of knowledge in virtually every field of science over the last 40 years. The Classroom of the Future™ is administered by the Erma Ora Byrd Center for Educational Technologies® at Wheeling Jesuit University in Wheeling, WV.

The Classroom of the Future serves as NASA's premier research and development program for educational technologies. In this capacity the Classroom of the Future develops and conducts research on technology-based learning materials.

About the Authors

The authors of this report are members of the Classroom of the Future's research and evaluation team.

Dr. Debbie Denise Reese
Educational Researcher

Dr. Beaumie Kim
Design Researcher

Dr. Deniz Palak
Educational Researcher and
Research and Evaluation Team Lead

Jeffrey Smith
Research Assistant

Dr. Bruce Howard
Design Researcher

Table of Contents

Executive Summary

This concept paper has four parts:

- Overview of the Classroom of the Future™ Inspiration Research Plan
- What Is Inspiration? A Summary of Its Theoretical Dimensions
- The Inspiration Challenge
- The Inspiration Labs Informal Event

Overview of the Classroom of the Future Inspiration Research Plan

The mission for NASA Education is to "inspire the next generation of explorers." Within this context the research team at the NASA-sponsored Classroom of the Future has set out to define and measure the construct known as "inspiration." By studying inspiration, the team hopes to provide research-based design principles to all of NASA Education for the development of robust, technology-based learning materials.

Our research plan is straightforward: conduct theoretical background research, develop hypotheses, and conduct studies to test those hypotheses. Each new cycle of research and tests will allow us to delve further into the construct and to provide more effective design principles, leading to greater impact. Of special note, our plan has unique elements that leverage our experience with NASA Education to provide immediate usability in the NASA network:

- The Classroom of the Future research team will test inspiration hypotheses using NASA-approved digital content materials. Lessons learned will apply in refining these materials for greater impact.
- The Classroom of the Future development team will enhance or create technology tools to test inspiration hypotheses. Effective inspiration tools that are produced would be scalable across multiple e-Education projects.
- Research studies will take place in testbeds where NASA materials are already being used. Through this process what we learn about teachers, students, and classroom applicability of NASA materials will have immediate implications for NASA Education.

Our goal for 2005 is to provide a preliminary theoretical framework for the construct and to begin operationalizing its dimensions. Our primary activities this year are to study the background research in this area, develop initial hypotheses, and conduct research studies to test those hypotheses. Our plan for each of these activities is discussed in detail in this paper.

What Is Inspiration? A Summary of the Theoretical Dimensions Underlying Inspiration

The research team has surveyed literature related to career education, social psychology, cognitive psychology, educational technology, and sociology domains to build a working model of inspiration. The investigation initially identified more than 100 variables and organized them into categories. These categories became the basis for independent, extended literature reviews that were synthesized into a systemic model of the dimensions of inspiration.

The Classroom of the Future identified five dimensions of inspiration: mental models, imagination, identity, creativity, and self-efficacy. The five dimensions have been synthesized into a preliminary model (the Model of Systemic Inspiration Growth) for Classroom of the Future researchers to use to test inspiration hypotheses.

The model is concerned with only a certain type of inspiration—Inspiration that will lead individuals to make productive life choices, especially those leading toward greater STEM (science, technology, engineering, and mathematics) literacy or STEM career involvement. Such productive life choices, we propose, prepare young people for the rigorous demands of a STEM career or even one within NASA.

Two hypotheses will be tested within the context of the Inspiration Challenge and the informal event. The details of the hypotheses will be defined and developed throughout this brief.

> **Hypothesis 1: Inspiration Challenge Hypothesis**
> Argumentation will enhance learner achievement along dimensions of the Classroom of the Future Model of Systemic Inspiration Growth.
>
> Explanation. *Argumentation is the practice of making and supporting hypotheses by discussing them with peers. Argumentation is a component of science practice. Researchers have found that argumentation increases learners' understanding of science practice and content. However, in order to successfully engage in social negotiations of beliefs and knowledge, learners must learn how to engage in argumentation. Researchers will test this hypothesis with a social argumentation tool. The tool will be designed to help learners successfully engage in argumentation.*
>
> **Hypothesis 2: Informal Event Hypothesis**
> A viable role model successfully accomplishing a science task will enhance a learner's self-efficacy that he or she can solve that task.
>
> Explanation. *People are more successful at accomplishing a goal when they perceive that they can be successful. An individual's perception of his or her own ability to succeed at a specific task is self-efficacy. One way to enhance self-efficacy for a specific task is to watch someone else succeed at the task. However, watching just anyone succeed will not enhance self-efficacy. Self-efficacy for accomplishing a goal grows only when the observer identifies with the successful individual. To be effective, a role model must be viable. Additionally, any growth in self-efficacy will be specific to the task observed. The Classroom of the Future will test this hypothesis with an affective role model tool. The tool will be designed to enhance learners' self-efficacy to accomplish a science task.*

The Inspiration Challenge

The inspiration lab team proposes a study in which an "Inspiration Challenge" serves as the classroom context. Using Classroom of the Future and NASA Explorer School testbeds, researchers will recruit teachers to participate in the competition. Participating teachers will use a NASA-approved digital content curriculum module over a period of three weeks. In this case e-Mission™: Operation Montserrat™ is the curricular module of choice. Operation Montserrat (http://e-Missions.net/om/teacher) places students in the role of scientists to forecast, plan, and make emergency recommendations concerning the hurricane and volcano events that threatened Montserrat on Sept. 4, 1996. Classrooms that demonstrate the greatest degree of inspiration will win prizes.

The challenge provides classroom laboratories in which to test one of the inspiration hypotheses. The hypothesis was derived from the literature review around mental models. Theory and prior research suggest that argumentation can enhance learners' mental models of science content and practice. We propose that argumentation and enhanced mental models will lead to greater quality and quantity of "flow" experiences.

To enable students to become trained in argumentation, the Classroom of the Future will develop a social inspiration tool to enhance students' ability to participate in argumentation and teachers' ability to mentor argumentation. During the Inspiration Challenge, researchers will test whether learner argumentation, as scaffolded by an argumentation tool and applied within Operation Montserrat, enhances learners' scores on instruments that measure the dimensions of inspiration.

The Inspiration Labs Informal Event

Informal youth teams, including Girl Scouts, Boy Scouts, 4-H, YWCA, community groups, and after-school clubs, will participate in robotics competitions. The team identified robotics competitions and workshops as a type of informal event that could be used to test components of the inspiration hypotheses. Based upon the literature, the Classroom of the Future identified the parameters of an affective tool that would enhance participants' success at working with challenging aspects of robotics programming. This led to formulation of the informal event hypothesis. The instrument that measures the amount of change caused by an affective tool and further details of the study design are outlined later in this brief.

Overview of the Classroom of the Future Inspiration Research Plan

NASA Education Goal 6: Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics

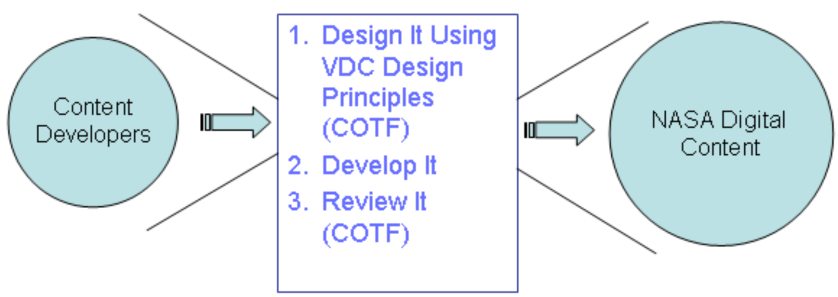
6.4 e-Education Objective: Increase student, teacher, and public access to NASA education resources via the establishment of e-Education as a principal learning support system.

6.4.2: Learning Tools and Materials: Demonstrate the effectiveness of NASA digital content materials in targeted learning environments.

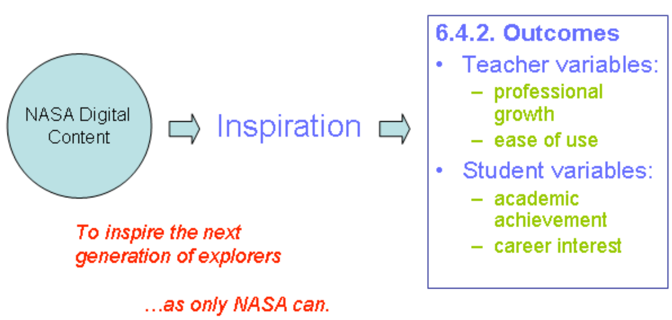
The mission for NASA Education is to "inspire the next generation of explorers." Within this context and the context provided by the objectives for e-Education outlined above, the research team at the NASA-sponsored Classroom of the Future has set out to define and measure the construct known as "inspiration." By studying inspiration, the Classroom of the Future™ hopes to be able to provide research-based design principles to all of NASA Education for the development of robust, technology-based learning materials.

How Does the Classroom of the Future Provide Services in this Area?

1. Assist in product design.
2. Conduct product review.
3. Define and understand inspiration.
4. Research effectiveness.



Classroom of the Future services 3 and 4 are the area of discussion in this paper. We propose that our research will enable the development of research methods in this area which will help further Objective 6.4.2. For example, the Inspiration Challenge study is designed specifically to address PART Measure 6.4.2 in the area of academic achievement and career interest:



Of special note, our plan has some unique elements built in that leverage our experience with NASA Education to provide immediate usability in the NASA network:

- The Classroom of the Future research team will test inspiration hypotheses using NASA-approved digital content materials. Lessons learned will apply in refining these materials for greater impact.

- The Classroom of the Future development team will enhance or create technology tools to test inspiration hypotheses. Effective inspiration tools that are produced would be scalable across multiple e-Education projects.
- Research studies will take place in testbeds where NASA materials are already being used. Through this process what we learn about teachers, students, and classroom applicability of NASA materials will have immediate implications for NASA Education.

Our research plan is straightforward—conduct theoretical background research, develop hypotheses, and conduct studies to test those hypotheses. Each new cycle of research will allow us to delve further into the construct and to provide more effective design principles, leading to greater impact.

Our goal for 2005 is to provide a preliminary theoretical framework for the construct and to begin operationalizing its dimensions. Our primary activities this year are to study the background research in this area, develop hypotheses, and conduct several research studies to test those hypotheses. Highlights from this research will be integrated into the Classroom of the Future Virtual Design Center (http://vdc.cet.edu/) to benefit NASA Education as a whole.

What Is Inspiration? A Summary of the Theoretical Dimensions Underlying Inspiration

To build a working model of inspiration, the research team surveyed theoretical and research-based literature in the following areas: career development, social psychology, cognitive psychology, educational technology, and sociology. The investigation led us to generate a list of more than 100 variables of importance, such as identity, motivation, attitudes, and self-efficacy, which were then organized into categories. These categories became the basis for a more thorough literature review. The results of this process are presented here.

Our search for a theoretical basis for inspiration's many dimensions was coupled with a simple pragmatic concern as well. Our relationship with various entities within NASA Education and our awareness of the importance of the NASA career pipeline led us to pare down the scope of this enormous task into a smaller, more NASA-specific definition of inspiration. That is, as a research team, we are most interested in those dimensions of inspiration that lead young people to make productive life choices leading toward greater STEM literacy and STEM career involvement.

We are most interested in those dimensions of inspiration that lead young people to make productive life choices leading toward greater STEM literacy and STEM career involvement.

Theory and pragmatism combined, our investigation has yielded five dimensions of inspiration to study: mental models, imagination, identity, creativity, and self-efficacy. The reader will note that many of our best ideas are derived from the work of Csikszentmihalyi, Schneider, and their colleagues (Csikszentmihalyi, 1996, 1997b; Csikszentmihalyi & Schneider, 2000) who have studied the concept of "flow" and youth identity development. This is described below.

What Is Inspiration? A Model of Systemic Growth

The five dimensions have been synthesized into a preliminary model (the Model of Systemic Inspiration Growth, see Figure 1 below) for Classroom of the Future researchers to use to test inspiration hypotheses. The model is concerned with only a certain type of inspiration: inspiration that will lead individuals to make productive life choices, especially those leading toward greater STEM literacy or STEM career involvement. Such productive life choices, we propose, prepare young people for the rigorous demands of a STEM career or even one within NASA. The model is outlined briefly here. A fuller explanation of each component is given further below, with citations.

The Five Dimensions

Figure 1 indicates that the five dimensions (mental models, imagination, identity, creativity, and self-efficacy) are all part of an interrelated system. That is, changes along one dimension may cause changes in other dimensions. If you examine the diagram closely, you will see that there are a total of 20 dimension-to-dimension possible cause-effect relationships. Changes in one dimension may also feed back into the dimension itself. We propose here that the mental models construct should be central because the literature indicates that mental models are a prerequisite for growth in the other dimensions.

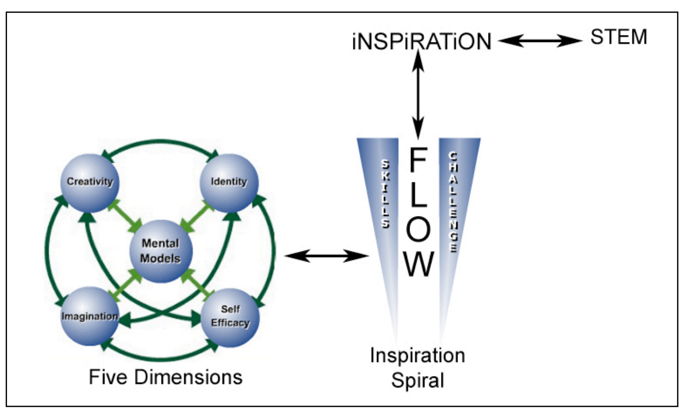


Figure 1. Model of systemic inspiration growth

The Flow Spiral

When students report above average levels of concentration, enjoyment, happiness, strength, motivation, and self-esteem, they are said to be in a state of "flow" (Csikszentmihalyi & Schneider, 2000). In a flow experience an individual perceives a balance of using relatively high levels of his or her skills and challenging tasks. Individuals characterize their high flow experiences as complete immersion in a task or experience. Adolescents who are in flow are the most likely to feel that what they are doing is important to their future goals. Pleasure that is rooted in the activity at hand is also experienced as being related to life's broader framework and thus to future development. (Csikszentmihalyi & Schneider, 2000). Thus, flow states are linked to productive life choices.

Examining the flow spiral from Figure 1, one can see that for students to be in a state of flow, they must progress through ever-increasing domain-specific <u>skills</u> (or discipline-specific skills) and <u>challenges</u> in an ever-widening progressive spiral. Changes in the five dimensions may create a ripple effect that travels through the bidirectional arrow to the flow spiral. As students grow along the five dimensions, and as they progress through a spiral of increasing skills and challenges, they will experience flow more often. Within the model inspiration begins as a temporary state and is thus susceptible to change. Typically, for an individual to progress from a state of inspiration toward sustained experiences of inspiration and productive life choices, that individual must receive support from their environment, such as family, community, and informal and formal education (Csikszentmihalyi & Schneider, 2000). Reoccurring states of inspiration may eventually become a trait that sustains an individual for the longer term. Over time and given enough flow experiences within a domain, flow may become a longer lasting personal trait.

Inspiration and STEM

We propose that greater flow leads to greater inspiration. In many ways flow is a measurable and outward manifestation of inspiration. For this reason our current research will focus on measuring and testing flow as a proxy for inspiration. Flow leads to productive life choices that lead to preparation for STEM careers. Attainment of a NASA STEM career is the result of a sustained series of efforts and achievement. It is the result of a trait known as inspiration.

Inspiration: Defining Dimensions

Dimension 1: Mental Model

Mental models, specifically in relation to science learning, include students' images of scientists, their ideas about the nature of science and scientific inquiry, and their science content knowledge. An understanding of what science is and what it means to do science is crucial for inspiration toward STEM careers and literacy.

Images of Scientists

Exposure determines a component of learners' images of scientists. In order to inspire students toward science careers, the positive aspects of scientists and scientific careers need to be emphasized in our schools and mass media (Mead & Métraux, 1957). Techniques have been developed to study students' images of scientists. Mead and Métraux (1967) used essays as a tool to study high school students' images of scientists. They analyzed a nationwide sample of essays from high school students about images of scientists. Their 1967 data showed that the students held positive images in terms of the benefits from the advancement of science but extremely negative images of science as their own or their spouses' career choices. Later studies have actually asked students to draw their images of scientists. The pictures were often stereotypical, such as images of a white male with lab coats and glasses (Chambers, 1983; Fort & Varney, 1989). Learners' images of scientists change as learners' awareness of scientists and science change.

Nature of Science and Scientific Inquiry

What does it mean to do science and to be a scientist? Nature of science refers to the beliefs about scientific knowledge and how it is developed (Lederman et al., 2002). National science education standards state, "The standards for the history and nature of science recommend the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures" (National Research Council, 1996, p. 107). Despite the curricular emphasis on enhancing students' conceptions of nature of science, research shows that K-12 students as well as their teachers do not have desirable understanding of the nature of science (Lederman et al., 2002). In order to inspire students toward science careers, learning environments must scaffold students' mental models of the nature of science and scientific inquiry. Learning environments that engage students in inquiry and activities situated within authentic science contexts scaffold construction of these mental models.

Science Content Knowledge

As an individual builds knowledge about any domain, he or she constructs a personal mental representation of that knowledge. Although this representation is affected by an individual's history, shared culture, environment, and whether the knowledge is constructed as a member of a group or in isolation, each individual's representation is personal and, to some degree, idiosyncratic. This representation is a mental model (A. L. Brown et al., 1986; Chi, 2000; Chi et al., 1994; Gentner & Stevens, 1983; Gilbert & Boulter, 2000; Johnson-Laird, 1983).

Mental models can be shared. Indeed, this is the goal of communication and one of the marks of cognition that determines what it means to be human and what the human race can accomplish. Although a shared model corresponds to someone's original mental model, it is never an exact duplicate (Gilbert et al., 2000).

Domain-specific mental models are the key to the other four dimensions and to flow. Sustained growth along any inspiration dimension requires increase in domain-specific mental models. Learning environments must help learners to construct robust, normative, and coherent mental models (Linn et al., 2004). In order to nurture the successive increases in creativity, imagination, identity, self-efficacy, and flow, an environment must provide the means for learners to construct domain-specific mental models.

Model building is a component of the practice of science:

- Analogy is used in the discovery of new knowledge and in the transfer of knowledge from one generation to the next (Kuhn, 1993).
- Scientists' private mental models are expressed to the community. If successful, those models become consensus models. Consensus models are tested, peer evaluated, and become scientific models when they are published in refereed journals (Gilbert et al., 2000).

When learners construct models of the science, they engage in an authentic science practice. A pedagogical methodology that engages learners in authentic mental model building would engage learners in a process that:

- Helps learners express their private mental models.
- Holds those models up to a group of peers.
- Validates those successful models through their peers.

These activities involve learners in the authentic scientific practice of creating and validating new knowledge through mental models. Argumentation is a pedagogical methodology that involves learners in these activities. It is a social activity that engages learners in dialog. Through argumentation students learn (a) to express their mental models as knowledge claims, (b) to warrant those claims, and (c) to consider and evaluate the knowledge claims of others through arguments and counterarguments (Nussbaum, 2004; Nussbaum et al., 2005). Argumentation then is used as a social tool to enhance learners' mental models of targeted domain knowledge. Argumentation facilitates student engagement in argument construction, critique, and interactive learner-to-learner model building (Nussbaum, 2004; Nussbaum et al., 2005).

Nussbaum (2004) studied the effect of instructions on the quality of students' argumentation. In the context of web-based chats, students generated more arguments if they were prompted to persuade or to generate reasons. Students instructed to persuade created arguments that were more adversarial. Instructions to generate reasons resulted in deeper arguments that investigated and integrated multiple perspectives. He and his colleagues (Nussbaum et al., 2005) also studied the effect of a brief web-based training on argumentation. This training could be considered as one prototype for social argumentation tools and studied for characteristics and functionalities. Within his study college students who received the training had better developed arguments. The arguments considered a greater number of factors (p. 1).

Theoretical Approaches to Knowledge Building

There are multiple approaches to conceptualization and study of human leaning and knowledge building. Selection of a particular approach often depends on the components of learning and learning environments that a researcher or instructional designer has identified for study or development. Social constructivists (Cobb & Yackel, 1996; Glasersfeld, 1995) concentrate on the sociocultural aspects of the meaning-making, and the learning community (e.g., the students, the teachers, etc.) is the focus. Argumentation follows from this prospective when it is used as a technique to enhance shared meaning-making. Scholars and designers who conceptualize meaning-making as situated learning (Greeno, 1997) emphasize the importance of authenticity. These scholars and designers would stress that teaching and learning of science should involve learners in authentic scientific activities. NASA's Classroom of the Future Virtual Design Center (http://vdc.cet.edu/) follows this orientation when it trains developers to design inquiry-based learning environments that are situated in authentic NASA science contexts, use NASA data, and involve learners in addressing NASA research questions. Instructional technology tools also follow this approach when they are designed to replicate authentic scientific instruments (Kim, 2004; Kim & Hay, 2005). One example of an authentic tool is the NASA Learning Technology Project's (http://learn.arc.nasa.gov/) Virtual Lab scanning electron microscope developed at NASA Kennedy Space Center. This virtual tool provides learners with lab experiences that simulate the look and feel of working with an actual scientific instrument. The cognitive approach (Anderson et al., 1997) focuses attention on the individual learner. An instructional design model that applies cognitive science metaphor theory (Gentner, 1983, 1989; Gentner & Holyoak, 1997) toward the design of instructional metaphors that enhance a learner's mental model of a science domain (Reese, 2003a, 2003b, 2004, 2005, October, 2003; Reese & Coffield, 2005) follows a cognitive approach. In application, the approaches often work together. For example, instructional metaphors can become a social tool if they are incorporated into classroom discourse.

Dimension 2: Imagination

Imagination is typically defined in dictionaries as the formation of mental images or concepts that are not present to the senses (Reader's Digest, 1996). The Classroom of the Future has selected a characterization of imagination developed by Etienne Wenger (1998). According to Wenger, imagination is "a process of expanding oneself by transcending our time and space and creating new images of the world and ourselves" (p. 176). As we will describe, Wenger's model of imagination aligns with the Classroom of the Future Model of Systemic Inspiration Growth by supporting the goal of developing identities and creativity from mental models of STEM domains, scientists, and science practice imagination. Characteristics of Wenger's model of imagination that are salient to productive life choices are those in which people "reinvent [themselves], [their] enterprises, [their] practices, and [their] communities" (p. 185). He considers imagination to be an important source of community engagement for learners. Imagined identities can reframe the learning experience of a given student. For example, Wenger (1998) speaks of two stonecutters who were asked what they were doing. One answered, "I am cutting this stone in a perfectly square shape," and the other responded, "I am building a cathedral" (p. 176). Although the two were engaged in the same activity, their responses indicate that their experiences of the activity and their sense of self are vastly different. Wenger further posits that the difference in their imagined relationship to their work and the world will have a profound effect on their ongoing learning.

Imaginative activities require the ability to disengage one's perceptions, transcending our time and space and creating new images of the world and ourselves. Wenger's (1998) example of this process is the girl who, when shooting a basketball in her driveway, envisions that she is standing in an arena with thousands of fans chanting her name. For Wenger, imagination focuses on "the creative process of producing new 'images' and of generating new relations through time and space that become constitutive of the self" rather than mere fantasy or withdrawal from reality (p. 177). Wenger describes the following processes as imaginative:

- Recognizing our experience in others.
- Connecting ourselves to an extended identity.
- Locating our engagement and practices in broader systems in time and space and multiple contexts.
- Sharing stories, explanations, and descriptions.
- Opening access to distant practices through visiting new places and people.
- Assuming the meaningfulness of foreign artifacts and actions.
- Creating models, reifying patterns, and producing representational artifacts.
- Documenting or reinterpreting history and using history to see the present as only one of many possibilities and the future as a number of possibilities.
- Generating scenarios and exploring novel ways of acting, possible worlds, and identities. (quoted or paraphrased from Wenger, 1998, p. 185)

Like the other dimensions within the Model of Systemic Inspiration Growth, imagination requires a personal ability to take the risks. Risk-taking allows one to explore and make novel connections (p. 185). Imagination also requires some playfulness. This has implications for learning environments, work environments, and for broader human social systems. In order for people to grow along a dimension of imagination, their environments and communities must make them feel secure enough to take risks. People's work, educational, and personal environments must afford time and appreciation for intellectual play.

Dimension 3: Identity

Merriam-Webster's Collegiate Dictionary (1993) defines identity as "the relation established by psychological identification," which is "psychological orientation of the self in regard to something (as a person or group) with a resulting feeling of close emotional association" (p. 575).

Identity emerges as one of the important constructs within the inspiration model. To generate inspiration toward the STEM career and literacy, learners must first establish a relation with STEM through the identification process. Identity is generally an unconscious process in which an individual constructs thoughts, feelings, and actions based upon mental models (Merriam-Webster, 1993). In the United States this identification process often reflects the popular culture of our young generation. The young often create their identity from entertainment or sports idols. In the United States today it is unlikely that many adolescents currently regard scientists or mathematicians as idols. A long history of identity research has been recently revived in the social sciences. Educational researchers are revisiting the concept as a potential research and development tool for education (Gee, 2001; Sfard & Prusak, 2005).

Gee (2001) defined identity as "being recognized as a certain 'kind of person' in a given context" (p. 99). Identity is not characterized as a person's internal state but as something inherent to the complexity of the person's social practices; thus, multiple identities are akin to the multiple memberships in the communities of the society (Gee, 2001; Wenger, 1998). Participation in the communities forms who we are, what we do, how we do what we do, and how we interpret what we do and what others do (Wenger, 1998).

In the context of education, learners establish relations within the learning context regarding how personally important or meaningful it is (e.g., how athletically talented students are supposed to excel in every activity in physical education class). Wenger (1998) interprets learning as social participation. The social participants learn by *doing* the peripheral role in the practices; they gain *meanings* of their practice through the learning experience. As they get closer to the core characteristics of community, they gain an increased sense of *belonging*. They shape their *identity* as the member of the community through the participating and learning experience (Wenger, 1998). Identity shapes a learning trajectory because previous experience is an essential component of an individual's learning practices.

The alignment of identity with the local learning context is significant for the performance of learners. However, the sense of belonging beyond the local context is what leads learners toward pursuing their future careers. The learning experience provides them with images of the world, possibilities, past and future, and themselves in relation to the world (Wenger, 1998). When they find themselves within their images of the world (mental models), they can coordinate their energies, actions, and practices to become a part of those images in the future.

Sfard and Prusak (2005) call these prospective identities *designated identities* as opposed to *actual identities*. They see learning as closing the gap between actual identities and designated identities and use identity as conceptual tool to analyze stories of learners about learning. Discourses, dialogues, and interactions, in fact, both shape identity and allow researchers to study and understand identity (Gee, 2001; Sfard & Prusak, 2005).

Some recent educational research on identity and science is focused on the analysis of verbal communication (discourse analysis) in science classrooms. Brown (2004), for example, videotaped and analyzed the discourses of ethnic minority high school students' science classrooms and suggested using specific scientific discourse (that is, scientific language such as the component of argumentation: claims, warrants, evidence, counterarguments, etc.) as an explicit component of curriculum. Other researchers (e.g., Helms, 1998) study how identities of teachers affect their teaching practices. Research and development of inspiration tools should include the study of learners' identity formation when the tools are used in actual classrooms.

Dimension 4: Creativity

"Creativity is any act, idea, or product that changes an existing domain or that transforms an existing domain into a new one...." A creative person is "someone whose thoughts or actions change a domain or establish a new domain" (Csikszentmihalyi, 1996, p. 28).

Csikszentmihalyi (1996) distinguished among modes that can be labeled as creativity or confused with it. He identified the individual who is quick with a response in a conversation or the individual who easily learns and makes connections among ideas as brilliant. Others, those who have an "innate ability to do something well" (p. 27) are identified as talented. Those individuals who experience the world in "novel and original ways" (p. 25) are personally creative. According to Csikszentmihalyi's classification, creativity with a capital "C" occurs only when a person (whether brilliant, creative, talented, or average) contributes a novel idea that is validated by experts and changes some aspect of culture. Thus, creativity requires three players:

- The domain (a system of knowledge, see definition above).
- The field (the experts or gatekeepers of that domain).
- The individual person who knows the domain, comes up with an original idea, and has that idea accepted by the experts in the field.

According to Csikszentmihalyi's (1996, p. 11) studies, creativity is an interaction between three components: a sociocultural context (a culture), an individual person, and a field of experts: "a culture that contains symbolic rules, a person who brings novelty into the symbolic domain, and a field of experts who recognize and validate the innovation" (p. 6) by which "a symbolic domain in the culture is changed" (p. 8). In other words, creativity is when individuals, situated within a culture, develop original ideas about a domain. In addition, in order for persons to be considered creative, those ideas must gain purchase within the group of individuals who are expert in that domain.

Creativity involves exploration and enjoyment of novelty and risk (p. 11). In general, creativity does not flourish in repressive environments in which people must devote attention toward ensuring their survival. Instead, creativity is engendered when environments are intellectually flexible, times are plentiful, and a culture's people sit at a nexus of diversity (e.g., the culture supports diversity, the majority of the people are exposed to and accept diverse people, customs, ideas, etc.; thus, the culture is a crossroad where many cultures intersect).

The opportunity for creativity is enhanced when people's basic needs are met and they have the luxury and support for contemplation and development of domain expertise. In order to envision new combinations of ideas for a particular domain (such as aeronautics or robotics), a person must build domain knowledge. When one builds domain knowledge, one is building mental models (one of the inspiration constructs) of domain concepts and the relations between them.

A creative person requires access to the targeted domain content knowledge and to the field of experts in that domain (Csikszentmihalyi, 1996). However, creative people do not have to have extremely high IQs. Instead, Csikszentmihalyi's research demonstrated that creative people (pp. 59-76):

- Use both divergent and convergent thinking.
- Must be able to discriminate between good and bad ideas.
- Must maintain both a disciplined and playful relationship with thinking and their targeted domain.
- Must be able to alternate between states of imagination (one of the inspiration model constructs) and reality.
- Must alternate between working states of introversion and extroversion.
- Must acknowledge their own contribution and the contribution of those whose work they built upon.
- Must possess strong combinations of characteristics usually associated as either masculine or feminine.
- Must be willing to learn a domain's traditional knowledge and yet think independently about it.
- Must maintain passionate commitment toward the practice of their work while retaining objective appraisal of it.
- Must maintain openness and sensitivity.

These findings are similar to those published by other scholars who have specialized in creativity research. Creativity is a component of what Robert J. Sternberg (1991) labels "synthetic giftedness." Sternberg (1997) considers all intelligence inert unless it is used to achieve important goals. According to Sternberg (1997), creativity requires a balance between the ability to come up with original, novel, and/or unique ideas and two other types of intelligence: analytical intelligence ("ability to analyze and evaluate ideas, solve problems, and make decisions," p. 191) and practical intelligence ("the ability to translate theory into practice and abstract ideas into practical accomplishments," p. 192). In other words, a truly creative person is able to move novel ideas into successful adoption and implementation. Sternberg adds the following characteristics to those of successfully intelligent creative people. Environments that nurture creativity also support these characteristics. Successfully creative people (Sternberg, 1997, pp. 200-219):

- Actively seek out and become role models.
- Question assumptions and encourage others to do so.
- Allow themselves and others to make mistakes.
- Take sensible risks and encourage others to do so.
- Seek out tasks for themselves and others that allow for creativity
- Define and redefine problems and help others to do so.
- Seek rewards for and reward creativity.
- Allow themselves and others time to think creatively.
- Understand that, almost by definition, creative people will engender obstacles (i.e., resistance to new and novel ideas) they must overcome.
- Tolerate ambiguity in themselves and tolerate ambiguity in others.
- Are willing to grow.
- Recognize the importance of person-environment fit.

While involved in a state of creative activity, an individual is so focused upon the activity that the individual is usually unaware of any self-consciousness, time, or distractions. People who are in a creative state forget about themselves, time, and their surroundings. Involvement in creative activity becomes autotelic, or self-reinforcing, and intrinsically satisfying. These characteristics correspond to the state of flow (Csikszentmihalyi, 1990; Csikszentmihalyi & Schneider, 2000). When individuals are being creative, they often experience flow (Csikszentmihalyi, 1996). The more highly creative an individual is, the more often that person experiences flow. The flow state is characterized by a perceived sense that skills and challenges for the activity are optimal (for that individual) and balanced.

Creativity is important at both the individual and the societal levels. At the individual level, creativity is relevant to solving real-life problems. At the societal level creative individuals pioneer progress in science and technology and the beauty in arts (Sternberg, 1999). This progress facilitates change at the global level. In fact, Starko (1995) argues that humans would have no advancement in art, literature, science, and invention if human creativity did not exist.

Creativity has also been identified as important within the education practices. The Center for Student Aspirations (National Center for Student Aspirations), located at the University of Maine, lists curiosity and creativity as critical motivating factors within the classroom. According to its research, creativity is characterized by inquisitiveness, eagerness, a strong desire to learn new or interesting things, and a desire to satisfy the mind with new discoveries. Curiosity triggers people to ask why, while creativity has them asking why not. The experience of curiosity and creativity allows people to become active learners, desiring and seeking new discoveries.

Dimension 5: Self-Efficacy

"Perceived self-efficacy refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3).

Self-efficacy theory is a component of Albert Bandura's social cognitive theory (Bandura, 2001b, p. 10). Social cognitive theory concerns agency, or the human ability to exercise control over life circumstances (Bandura, 1997). According to Bandura (2001b), an individual's personal agency is determined by intentionality (plans of action), forethought (the analysis of internal and external conditions in shaping one's plans for executing intentions), self-reactiveness (self-motivation and regulation), and self-reflectiveness (self-examinations of one's thoughts and actions as verified by consequences and world knowledge). Efficacy is thought to be a core mechanism of personal agency. It is the "belief that one has the power to produce effects by one's actions" (p. 10). Accumulations of empirical evidence cited by Bandura (1995a, 1997, 2001b) indicate that people shape their actions and chart the courses of their lives based upon their perceived self-efficacy. Studies have shown that self-efficacy beliefs are "good predictors of academic achievement and subsequent career choices and decisions" (Pajares, 2001), both directly and indirectly through other factors (Bandura, 2001a, p. 2). Efficacy beliefs regulate human functioning through four major, often mutually activated processes (Bandura, 1995a). Three of these processes help people to create "beneficial environments and exercise control over daily life" (p. 10). These are cognitive, motivational, and affective processes. During the fourth, selection processes, individuals shape their lives by the choices they make.

Self-efficacy theory provides explicit guidelines on how to enable people to "exercise influence on how they live their lives" (Bandura, 1997, p. 10). Efficacy can be built through mastery experiences: "acquiring the cognitive, behavioral, and self-regulatory tools for creating and executing appropriate courses of action to manage ever-changing life circumstances" (Bandura, 1995a, p. 3). In agreement with Csikszentmihalyi's flow theory (Csikszentmihalyi, 1990; Csikszentmihalyi & Schneider, 2000), Bandura (1995a, p. 3) stressed that "a resilient sense of efficacy requires experience in overcoming obstacles through perseverant effort." Challenges that include setbacks and difficulties enhance the resilience of efficacy. Studies also demonstrated that vicarious experience through social models can create and strengthen efficacy. To be effective at enhancing efficacy, role models must be perceived as similar to the observer, and the role model must succeed. Competent models can also "transmit knowledge and teach observers effective skills and strategies for managing environmental demands" (p. 4). Social persuasion can also affect perceived efficacy; however, it is easier to undermine efficacy beliefs than to enhance them. In addition to conveying positive appraisals, successful efficacy builders construct environments and situations within which people can successively approximate capability and succeed. One example might be a learning environment structured to afford cognitive apprenticeship (Collins et al., 1989) through scaffolding and fading.

Efficacy aligns with flow theory (Csikszentmihalyi, 1990; Csikszentmihalyi & Schneider, 2000) in another way. Highly efficacious individuals approach challenges as tasks to be mastered rather than as threats. This enhances intrinsic interest and deep engrossment in the activity (Bandura, 1995a, p. 11).

Efficacy is a domain specific rather than general (omnibus) construct (Bandura, 1997). In fact, there is no general measure of self-efficacy (Bandura, 2001a). Psychosocial tests (scales) that measure perceived efficacy have been found to be highly reliable, but only if they are constructed to measure domain-specific self-efficacy.

Flow: A Proxy for a State of Inspiration

The flow construct appears in the Classroom of the Future Model of Systemic Inspiration Growth (Figure 1). A flow experience is defined as one in which an individual perceives a balance of using relatively high levels of their skills and challenging tasks. Individuals characterize their high flow experiences as complete immersion in a task or experience. Adolescents who are in flow are the most likely to feel that what they are doing is important to their future goals. Pleasure that is rooted in the activity at hand is also experienced as being related to life's broader framework and thus to future development (Csikszentmihalyi & Schneider, 2000). Thus, flow states are linked to productive life choices.

We propose that greater flow leads to greater Inspiration. In many ways flow is a measurable and outward manifestation of inspiration. For this reason the current research will focus on measuring and testing flow as a proxy for inspiration. Flow leads to productive life choices that lead to preparation for STEM careers.

We introduce the flow construct here with an excerpt from a recent publication by Alan Lightman. He is a scientific researcher and has held academic appointments in astronomy, astrophysics, and physics at Cornell, Harvard-Smithsonian Center for Astrophysics, and Massachusetts Institute of Technology. The excerpt is Lightman's description of his first experience and success with original research (Lightman, 2005).

It is helpful to review his narrative for a number of reasons. First, Lightman is a successful astrophysicist. His experience of flow is the type of inspiration cultivated in and by individuals who make the productive life choices that qualify them for NASA careers. Second, his is a textbook case of the state of flow as it has been defined and studied by scientists (Csikszentmihalyi, 1990, 1997b; Csikszentmihalyi & Schneider, 2000). Third, Lightman's description was produced independently from the flow research studies and publications. Thus, Lightman's description provides corroboration of the connection between the state of inspired science practice and the flow construct.

> A year or two after college, I had my first true experience with original research. It was an experience that I can compare only to my first love affair. At the time I was 22 years old, a graduate student in physics at the California Institute of Technology. My thesis advisor at Caltech was Kip Thorne, only 30 himself but already a full professor....(p. 13)
>
> "...I was both thrilled and terrified by my assignment. Until this point in my academic life, my theoretical adventures had consisted mainly of solving homework problems. With homework problems the answer was known. If you couldn't solve the problem yourself, you could look up the answer in the back of the book or ask a smarter student for help. But this research problem with gravity was different. This answer wasn't known. And even though I understood that my problem was inconsequential in the grand sweep of science, it was still original research. No one would know the answer until I found it. Or failed to find it.

After an initial period of study and work, I succeeded in writing down all the questions I thought relevant. Then I hit a wall. I knew something was amiss, because a simple result at an early stage in the calculation was not coming out right. But I could not find my error. And I didn't even know what kind of error. Perhaps one of the equations was wrong. Or maybe the equations were right, but I was making a silly arithmetic mistake. Or perhaps the conjecture was false but would require an especially devious counterexample to disprove it. Day after day I checked each equation, pacing back and forth in my little windowless office, but I didn't know what was wrong. This confession and failure went on for months. For months, I ate, drank, and slept my research problem. I began keeping cans of tuna fish in a lower drawer of the desk and eating meals in my office.

Then one morning, I remember that it was a Sunday morning, I woke up about 5 a.m. and couldn't sleep. I felt terribly excited. Something strange was happening in my mind. I was thinking about my research problem and was deeply into it. I was seeing it in ways I never had before. The physical sensation was that my head was lifting off my shoulders. I felt weightless. And I had absolutely no sense of self. It was an experience completely without ego, without thought about consequence or approval or fame. Furthermore, I had no sense of my body. I didn't know who I was or where I was. I was simply spirit, in a state of pure exhilaration. The best analogy I've been able to find for that intense feeling of creative moment is sailing a round-bottomed boat in strong wind. Normally, the hull stays down in the water, the friction's drag greatly limiting the speed of the boat. But in high wind every once in a while the hull lifts out of the water, and the drag goes instantly to near zero. It feels like a great hand has suddenly grabbed hold and flung you across the surface like a skimming stone. It's called planing.

So I woke up at 5 to find myself planing. Although I had no sense of my ego, I did have a feeling of rightness. I had a strong sensation of seeing deeply into the problem and understanding it and knowing that I was right—a certain kind of inevitability. With these sensations surging thorough me, I tiptoed out of my bedroom, almost reverently, afraid to disturb whatever strange magic was going on in my head, and I went to the kitchen. There, I sat down at my ramshackle kitchen table. I got out the pages of my calculations, by now curling and stained. A tiny bit of daylight was starting to seep through the window. Although I was oblivious to myself, my body, and everything around me, the fact is I was completely alone. I don't think any other person in the world would have been able to help me at that moment. And I didn't want help. I had all of these sensations and revelations going on in my head, and being alone with all that was an essential part.

Somehow, I had reconceptualized the project, spotting my error of thinking, and begun anew. I'm not sure how this rethinking happened, but it wasn't by going from one equation to the next. After a while at the kitchen table, I solved my research problem. I had proved that the conjecture was true. The equal acceleration of the book and the cannonball does indeed require that gravity be geometrical. I strode out of the kitchen, feeling stunned and powerful. Suddenly I heard a noise and looked up at the clock on the wall and saw that it was two o'clock in the afternoon.

I was to experience this creative moment again with other scientific projects. But this was my first time. As a novelist, I've experienced the same sensation. When I suddenly understand a character I've been struggling with or find a lovely way of describing a scene, I am lifted out of the water, and I plane. I've read the accounts of other writers, musicians, and actors, and I think that the sensation and process are almost identical in all creative activities. The pattern seems universal: The study and hard work. The prepared mind. The being stuck. The sudden shift. The letting go of control. The letting go of self. (pp. 15-18)

This is a classic description of inspiration, experienced as flow. Individuals characterize their high flow experiences as complete immersion in a task or experience. While participating in a flow experience, people feel "completely without ego." They often report a loss of a sense of time. Lightman's description parallels the description developed by psychologist Csikszentmihalyi (1990) during the pioneering research in which he developed the Experience Sampling Method (ESM). This is the same construct operationalized by Csikszentmihalyi and Schneider (2000) during their Sloan study of youth and preparation for the world of work. The flow construct appears in the Classroom of the Future Model of Systemic Inspiration Growth (see Figure 1), and flow is the construct the Classroom of the Future will use within the Inspiration Challenge as a proxy for the state of Inspiration. Schneider is a consultant for the Classroom of the Future's study of flow within the 2005 Inspiration Challenge. The Classroom of the Future definition of flow derives from the work of Csikszentmihalyi, Schneider, and their colleagues (Csikszentmihalyi, 1996, 1997b; Csikszentmihalyi & Schneider, 2000)

Operational Definition of Flow

Flow is defined as an experience perceived by an individual as providing a balance of relatively high levels of skill and challenge (see Figure 2). Adolescents in flow report

> ...Levels above their own averages for concentration, enjoyment, happiness, strength, motivation, and self-esteem as well as the feeling that the activities in which they are engaged are important to their futures. Adolescents who are in flow are the most likely to feel that what they are doing is important to their future goals. Pleasure that is rooted in the activity at hand is also experienced as being related to life's broader framework and thus to future development (Csikszentmihalyi & Schneider, 2000).

Thus, flow states are linked to productive life choices.

Flow is intrinsically reinforcing. A flow experience is defined as autotelic (Csikszentmihalyi, 1990), because "it is a self-contained activity, one that is done not with the expectation of some future benefit, but simply because the doing itself is rewarding" (p. 67). The term is derived from the Greek translations of auto (self) and telos (goal). People will tend to repeat activities that put them in a state of flow. In order for people to remain in a state of flow or re-experience flow, they must experience successive cycles of increasing skills and challenges.

Flow theory (Csikszentmihalyi, 1997a) predicts state continuums and a challenge/skills plane, subdivided into states (see Figure 2). According to flow theory, when both challenges and skills are too easy, people are apathetic (see the bottom left square in Figure 2). When tasks, activities, or goals are too challenging, people become anxious (the top left square). When skills are required but lacking in challenge, people become bored (the bottom left square). The state continuum along the challenge axis runs from apathy to anxiety. The state continuum along the skills axis runs from apathy to relaxation.

Once people have entered into a state of flow, they can regain or return to flow if they continue to cycle through increasing levels of challenge and skills, as in the top right segment of the graph in Figure 2. For example, one moves from flow into more challenging demands that in turn require more skills and back into flow. Flow is enjoyable, self-reinforcing, and motivational. Therefore, flow supports individuals in learning the skills necessary to succeed at the corresponding flow challenges. A person who regularly experiences a great deal of flow has an autotelic personality (Csikszentmihalyi, 1990). Autotelic personalities are self-actualized because their motivation is internal rather than external.

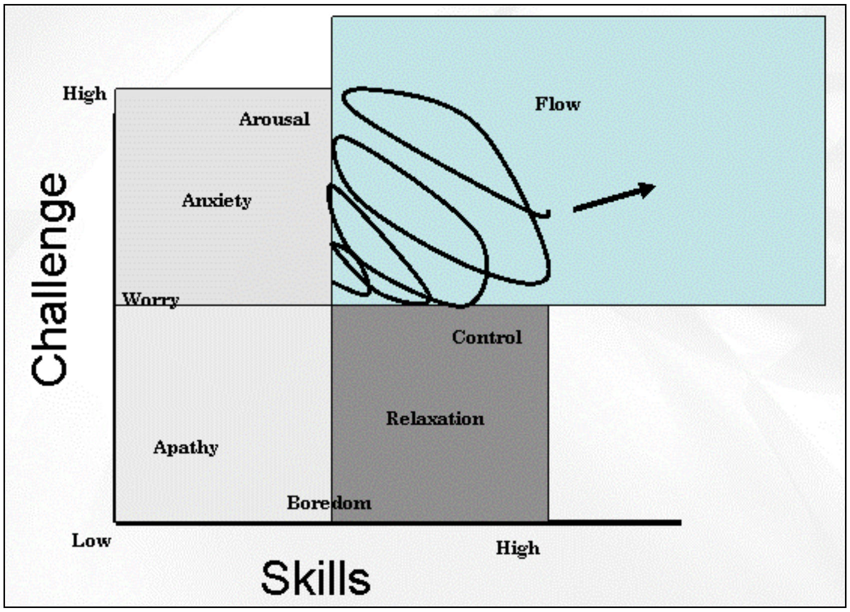


Figure 2. The flow spiral between increasing challenge and increasing skill

The figure illustrates the state continuums that run (a) from apathy to arousal because of increases in challenge and (b) from apathy to control because of increases in skills. Flow, or optimal experience, occurs when an individual perceives both skills and challenges as high, as illustrated by the blue rectangle. For an individual to experience repeated flow response to an activity, an individual's perception of personal skill level engaged in that activity and challenge presented by the activity must both grow. The spiral represents this growth (Csikszentmihalyi, 1990, 1996, 1997a, p. 31; Csikszentmihalyi & Schneider, 2000).

Csikszentmihalyi developed the experience sampling method to measure changes in individual's flow state over time (Csikszentmihalyi, 1990; Csikszentmihalyi & Schneider, 2000). Flow is measured through analysis of a participant's repeated self-reports of perceived levels of challenge and skills over time. Using the ESM, participants in a study are randomly signaled to record the levels of skill and challenge they are experiencing at the moment of prompting. Participants record their level of skill and challenge on a 10-point scale from low (0) to high (10), rating:

- Challenges of the activity?
- Your skills in the activity?

Typically, researchers use a randomly beeping pager (with a wristwatch appearance) that signals participants to record their perceptions of the moment's level of skills, challenges, and other dimensions of the quality of experience (e.g., happiness, concentration, enjoyment), Other systems can be used to signal an experience sampling. The signals must be produced at random intervals, precluding participant ability to anticipate data collection. Data is collected over time for all participants and then statistically analyzed. Two types of measurements of flow are derived from the reported levels of challenge and skill.

Flow State

The first calculation is a measure of state. An individual is defined as being in a state of flow when "levels of both challenge and skill [are] above his or her average" (Csikszentmihalyi & Schneider, 2000, p. 100). Three key states from Figure 2 are also calculated as a comparison of challenge level and skill level:

> *Anxiety*, in which the challenge of the activity is higher than the average but the required skill is lower; *relaxation,* in which skill is reported as higher than average but challenge is lower; and *apathy*, in which both challenge and skill are below the person's [average] (p. 100).

Csikszentmihalyi and Schneider (2000) found that anxiety reduces adolescents' motivation. Anxiety causes a "strong desire to be doing something else" (p. 101). Although adolescents' concentration is high during anxiety, their reported enjoyment, happiness, strength (as opposed to feeling weak), and self-esteem are low. As we would predict from the symmetrical reflective dyads, adolescents' reactions to relaxation is almost the opposite of their reaction to anxiety. During relaxation concentration and future importance are low, and the other dimensions are high. Teenagers report the lowest quality of experience while in apathetic states. Apathetic activities include such experiences as "just hanging out," or watching television.

Autotelic Personality

Autotelic personality is a relative measure in which participants are ranked against each other. When Csikszentmihalyi and Schneider (2000) used the autotelic personality scores in their analyses, they used the mean level of flow to rank participants. Study participants within the top quartile (those with the highest flow) were considered high autotelic personalities, and those within the bottom quartile (those with the lowest flow) were considered low autotelic personalities.

The Inspiration Challenge

Overview

The Classroom of the Future Operational Plan for 2005 specified several parameters for the Inspiration Challenge:

- The focus of the challenge will be selected components of inspiration hypotheses.
- The challenge participants will be drawn from Classroom of the Future and NASA Explorer Schools testbeds.
- Instructional materials should be NASA-approved digital content.
- The inspiration lab team will develop an instrument to measure growth in Inspiration.
- The inspiration lab team will use the results of the Inspiration Challenge to demonstrate the effectiveness of NASA digital content (2005 APG 6.4.2).

Accordingly, the inspiration lab team proposes a study in which an "Inspiration Challenge" serves as the classroom context. Using Classroom of the Future and NASA Explorer School testbeds, Classroom of the Future researchers will recruit teachers to participate in the competition. Participating teachers will use a NASA-approved digital content curriculum module over three weeks. In this case, e-Mission™: Operation Montserrat™ is the curricular module of choice. Operation Montserrat (http://e-Missions.net/om/teacher) places students in the role of scientists to forecast, plan, and make emergency recommendations to the hurricane and volcano events that threatened Montserrat on Sept. 4, 1996. The classrooms that demonstrate the greatest degree of inspiration will win prizes.

The challenge provides classroom laboratories in which to test one of the inspiration hypotheses. The hypothesis was derived from the literature review around mental models. Theory and prior research suggest that argumentation can enhance learners' mental models of science content and science practice. We propose that argumentation and enhanced mental models will lead to greater quality and quantity of flow experiences.

> **Hypothesis 1: Inspiration Challenge Hypothesis**
> Argumentation will enhance learner achievement along dimensions of the Classroom of the Future Model of Systemic Inspiration Growth.

To enable students to become trained in argumentation, the Classroom of the Future will develop a social inspiration tool to enhance (a) students' ability to participate in argumentation and (b) teachers' ability to mentor argumentation. During the Inspiration Challenge, the Classroom of the Future lab will test whether learner argumentation, as scaffolded by an argumentation tool and applied within Operation Montserrat, enhances learners' scores on instruments that measure the dimensions of inspiration.

Prior Work in this Area

This study will leverage NASA's and the Classroom of the Future's investment from prior years in the assessment materials developed by Dr. Daniel Hickey and his team. Argumentation is the foundation for Hickey's multilevel assessment implementation.

Additionally, the design will build on the seven-year Sloan Study of Youth and Social Development conducted by the Alfred P. Sloan Working Family Center (http://www.sloanworkingfamilies.org/) at the University of Chicago and the National Center for Research (http://www.norc.uchicago.edu/).

The study was funded by the Alfred P. Sloan Foundation (http://www.sloan.org/main.shtml). The Sloan Study (Csikszentmihalyi & Schneider, 2000) examined the relationships among demographics, dimensions of experience (such as engagement, self-esteem, positive affect, and salience), flow, and youth's decisions toward productive life choices, specifically regarding work and careers for U.S. adolescents. The construct of flow (the flow state) was central to the study. It was operationalized (as described above) on the level of the individual study participant as a perception that an experience requires above average skills and presents above average challenges.

The Inspiration Challenge Hypothesis

Argumentation will enhance learner achievement along dimensions of the Classroom of the Future Model of Systemic Inspiration Growth.

More specifically, we suggest that a social argumentation tool that scaffolds learners' ability to engage in argumentation will enhance their achievement along dimensions of the Classroom of the Future Model of Systemic Inspiration Growth. The tool will enhance the following:

1. *Mental models* of the targeted science content.
2. *Mental models* of argumentation, and thus of the practice of the nature of science and scientific inquiry.
3. *Skills* and ability to meet the *challenges* of the learning environment.
4. *Identity:* the ability to identify with the practice of science.
5. *Imagination*: the ability to imagine solutions to the Operation Montserrat scenarios.
6. *Self-efficacy* at argumentation and responding to the Operation Montserrat scenario.
7. Learners' level of *flow*.

The Inspiration Challenge Study Design

The Inspiration Challenge study design is illustrated in Figure 3. The week before the study begins, all participants within the Inspiration Challenge will take an academic achievement pretest (a proxy for a high-stakes, nationally standardized achievement test) and a prestudy survey (measuring career orientation and inspiration dimensions: self-efficacy, mental models of content, science practice, and scientists). Treatment participants and their teachers are those who will receive a social argumentation tool.

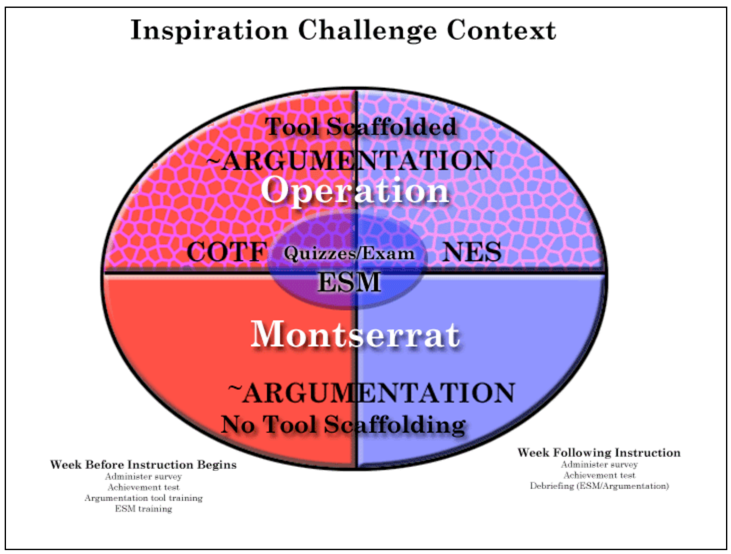


Figure 3. The Inspiration Challenge study design.

All study participants will complete pre-mission Operation Montserrat instructional activities. At the conclusion of each section of instruction, participants will take a quiz (developed by an externally contracted team). When the quiz is returned, students will work in teams to correct the answers to the quiz. The treatment group, scaffolded by the argumentation tool, will engage in argumentation techniques as they work with their team to correct the answers. At the conclusion of all units, all participants will complete a test over all units and work as a team to correct their answers. Once again, the treatment group, scaffolded by the social argumentation tool, will engage in argumentation techniques as they work with their team to correct the answers.

All participants and their teachers will practice completing the ESM instrument that will be used throughout the study. Periodically and randomly throughout the unit, all teachers and learners will be signaled to complete the ESM instrument. Learners will be randomly sampled at least 15 times. The instrument is short, and each response should take participants less than three minutes to complete.

After the test participants will retake the survey and high-stakes assessment proxy as a posttest measure. They will also retake selected portions of the prestudy survey.

The Inspiration Challenge Classroom Context

Using Classroom of the Future and NASA Explorer School testbeds, researchers will recruit teachers to participate in the competition. Participating teachers will use a NASA-approved digital content curriculum module (in this case, e-Mission: Operation Montserrat) over a period of three weeks. The classrooms that demonstrate the greatest degree of inspiration will win prizes.

Parameters for the competition, submission of materials, and judging will be distributed to all participants. We envision three $1,000 prizes for the treatment group and three $1,000 prizes for the control group. Prize money will be distributed with the stipulation that it be used to purchase materials for each winning teacher's science class. A small plaque would also add to the meaning and lasting effect of the competition for winners. We have also discussed awarding honorable mention certificates. Each teacher will also receive a letter for his or her personnel file demonstrating participation in the Inspiration Challenge.

Inspiration Challenge Instruments

Instrumentation for the Inspiration Challenge study will be adapted, in part, from the Sloan Study instruments (Csikszentmihalyi & Schneider, 2000). The Sloan Study principal investigator was Dr. Barbara Schneider (http://sociology.uchicago.edu/faculty/schneider/), a consultant for this study. Representatives from the Classroom of the Future research team met with Schneider and her team at the Sloan Center in Chicago to discuss study instrumentation, data setup, and analysis.

- Experience Sampling Method instrument: Measures flow and qualities of experience, such as confidence, happiness, and concentration.
- Career Orientation Survey: Measures student's orientation toward work, occupational expectations, and knowledge of NASA careers.
- Family Life Survey: Measures family demographics (completed by parents).
- Student Profile Survey: Measures other model dimensions, such as mental models of science, interest in science, self-efficacy.
- Multilevel assessments: Quizzes, curriculum-oriented exam, and a standards-oriented test.

The Inspiration Labs Informal Event

The Classroom of the Future cooperative agreement operational plan for 2005 specified several parameters for the informal event.

- Develop study protocols based upon an inspiration hypothesis involving an affective tool.
- Design and conduct the study in the context of an informal event conducted at the Center for Educational Technologies® or a partner informal site.

The Informal Event Hypothesis

A viable role model successfully accomplishing a science task will enhance a learner's self-efficacy that he or she can solve that task.

More specifically, we suggest that an affective tool that provides a viable role model successfully accomplishing a science task will enhance a learner's self-efficacy that he or she can solve that task.

The Informal Event Study Design

Studies have shown that task-specific vicarious experience provided by successful role models can enhance self-efficacy, but only if the observer (in our case, a learner) identifies with the role model. The Classroom of the Future has applied self-efficacy theory toward enhancing learners' ability to succeed at a complex task related to NASA science. Participants will be recruited to participate in informal workshops in which they build robots using LEGO® MINDSTORMS™ technology. Some participants will be preparing for FIRST (For Inspiration and Recognition of Science and Technology) LEGO® League competitions (http://www.usfirst.org/jrobtcs/flego.htm). Others will be participating as a recreational or informal educational activity.

Dr. Debbie Denise Reese, a member of the research team, has participated in several large-scale, multiyear studies that constructed and revised a collective efficacy scale and analyzed the impact of the Internet on community collective efficacy and social activism (Carroll & Reese, 2003; Kavanaugh et al., 2005; Kavanaugh et al., submitted; Kavanaugh et al., 2003, in press-a, in press-b). Albert Bandura, the research guru in this area, had been a consultant on that project.

The study design is simple. The Classroom of the Future will provide a series of workshops in robotics. Participants will be area young people who take part in one of these workshops. Once the participants are introduced to the concept of robotics and sensors, they will complete an inventory that will measure their individual self-efficacy. All participants will receive computer-mediated instruction on the use and programming of robotic sensors (see Figure 4).

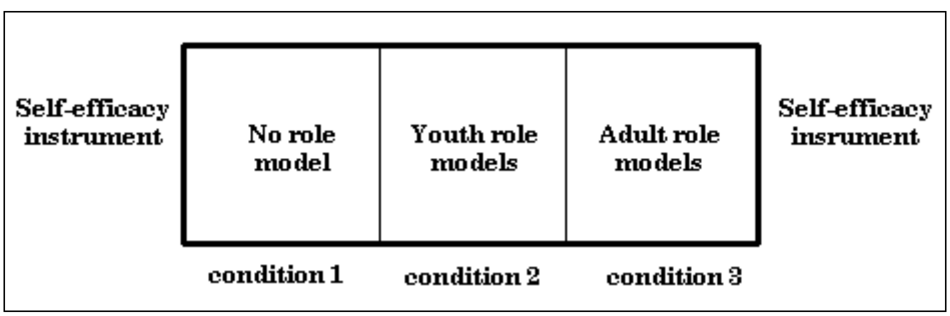


Figure 4. The informal event study design.

Participants will be randomly assigned to one of three study conditions. All conditions will receive the same computer-based instruction about how to program robotics sensors. Participants in condition 1 will receive only that instruction. Condition 2 participants will receive the same instruction along with video of demographically appropriate role models (same age, same gender, same race, same ethnicity, same socioeconomic class) solving the robotics sensor challenges. Condition 3 will receive the same instruction, along with a video of adults successfully solving the robotics sensor problems. Participants will finish the workshop by carrying out their robotics tasks and retake the self-efficacy instrument. We predict that the youth participants will identify more strongly with condition 2, and that condition 2 participants' self-efficacy for programming robotics sensors will increase.

Instruments

- Self-efficacy scale: Measures participant's perceived ability to program LEGO robots and to program sensors.
- Identify constructs: Measures learner's identification with the role model provided within the instruction.

Multiple Informal Events

The Classroom of the Future proposes to host multiple informal events and multiple robotics workshops over the course of the 2005 contract. This will allow the inspiration lab to perfect its instruction and the self-efficacy instrument. Replication is very important in any type of scientific research (Lindner, 1997). Replication of findings over multiple events will allow the Classroom of the Future and NASA to make stronger claims about the effect of the affective tool upon learners' self-efficacy. In addition to hosting the events at the Center for Educational Technologies on the Wheeling Jesuit University campus, we would like to investigate partnerships with other venues, such as Oglebay Institute in Wheeling and the Carnegie Science Center in Pittsburgh. We may even eventually want future studies to include family workshops.

As a culminating event, the Center for Educational Technologies will host a FIRST LEGO® League competition on Dec. 10, 2005. Teams will register through the Center for Educational Technologies from mid-September through Oct. 14, 2005. The inspiration lab would like to recruit those teams as participants in this study. The inspiration lab would provide the sensor instruction to these teams, randomly assigning them to treatment and control conditions (see Figure 5). Teams would complete the self-efficacy instrument multiple times during the fall, allowing the collection of longitudinal data.

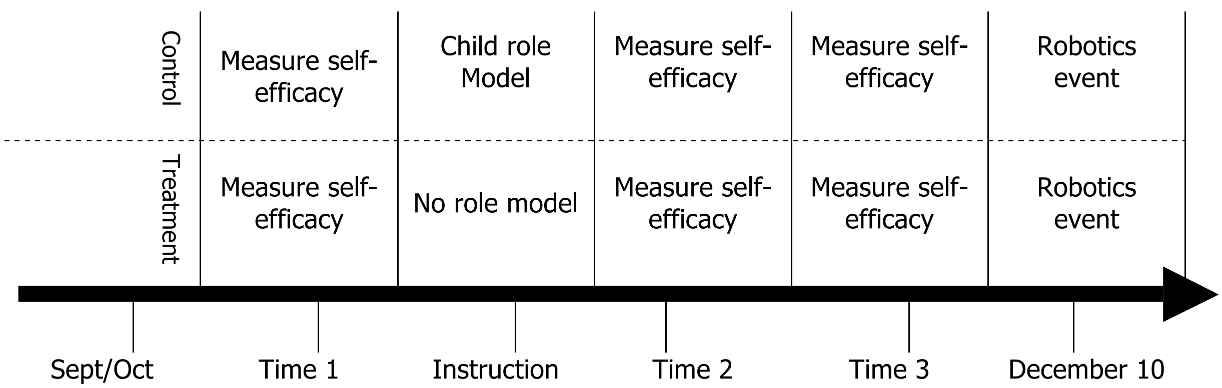


Figure 5. The informal event longitudinal study.

References

Anderson, J. R., Reder, L. M., & Simon, H. A. (1997). Situative versus cognitive perspectives: Form versus substance. *Educational Researcher, 26*(1), 18-21.

Bandura, A. (1995a). *Self-efficacy in changing societies*. New York: Cambridge University Press.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman and Company.

Bandura, A. (2000). Exercise of human agency through collective agency. *Current directions in psychological science, 9*(3), 75-78.

Bandura, A. (2001a). Guide for constructing self-efficacy scales: (available from Frank Pajares, Division of Educational Studies, Emory University, Atlanta, GA 36322).

Bandura, A. (2001b). Social cognitive theory: An agentic perspective. *Annual review of psychology, 53*, 1-26.

Bandura, A. (Ed.). (1995b). *Self-efficacy in changing societies*. New York: Cambridge University Press.

Brown, A. L., Kane, M. J., & K., E. (1986). Young children's mental models determine transfer across problems with a common goal structure. *Cognitive Development, 1*, 103-122.

Brown, B. A. (2004). Discursive identity: Assimilation into the culture of science and its implication for minority students. *Journal of Research in Science Teaching, 41*(8), 810-834.

Carroll, J. M., & Reese, D. D. (2003). Community collective efficacy: Structure and consequences of perceived capacities in the Blacksburg electronic village, *Proceedings of the HICSS-36: Hawaii International Conference on System Sciences (CD/ROM)*. Hawaii: IEEE Computer Society (publication in IEEE Digital Library). (Nominated for best paper). Ten pages.

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist test. *Science Education, 67*(2), 255-265.

Chi, M. T. H. (2000). Self-explaining expository texts: The dual processes of generating inferences and repairing mental models. In R. Glaser (Ed.), *Advances in instructional psychology* (pp. 161-238). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chi, M. T. H., de Leeuw, N., Chiu, M.-H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science, 18*, 439-477.

Cobb, P., & Yackel, E. (1996). Constructivist, emergent, and sociocultural perspectives in the context of developmental research. *Educational Psychologist, 31*(3/4), 163-174.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-493). Hillsdale, NJ: Lawrence Erlbaum Associates.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience* (HarperPerennial ed.). New York: Harper & Row Publishers.

Csikszentmihalyi, M. (1996). *Creativity: Flow and the psychology of discovery and invention*. New York: HarperCollins Publishers.

Csikszentmihalyi, M. (1997a). *Finding flow: The psychology of engagement with everyday life*. New York: HarperCollins Publishers.

Csikszentmihalyi, M. (1997b). Flow and creativity. *NAMTA Journal, 22*(2), 60-97.

Csikszentmihalyi, M., & Schneider, B. (2000). *Becoming adult: How teenagers prepare for the world of work* (1st ed.). New York: Basic Books.

Fort, D. C., & Varney, H. L. (1989). How students see scientists: Mostly male, mostly white, and mostly benevolent. *Science and Children*, 8-13.

Gee, J. P. (2001). Identity as an analytic lens for research in education. *Review of Research in Education, 25*, 99-125.

Gentner, D. (1983). Structure mapping: A theoretical framework for analogy. *Cognitive Science, 7*, 155-170.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 199-241). New York: Cambridge University Press. (Reprinted in *Knowledge acquisition and learning*, 1993, 673-694.)

Gentner, D., & Holyoak, K. J. (1997). Reasoning and learning by analogy: Introduction. *American Psychologist, 52*(1), 32-34.

Gentner, D., & Stevens, A. L. (Eds.). (1983). *Mental models*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Gilbert, J. K., & Boulter, C. J. (2000). *Developing models in science education*. Boston: Kluwer Academic Publishers.

Gilbert, J. k., Boulter, C. J., & Elmer, R. (2000). Positioning models in science education and in design and technology education. In J. K. Gilbert & C. J. Boulter (Eds.), *Developing models in science education*. Boston: Kluwer Academic Publishers.

Glasersfeld, E. v. (1995). *Radical constructivism: A way of knowing and learning*. New York: Routledge Falmer Press.

Greeno, J. (1997). On claims that answer the wrong question. *Educational Researcher, 26*(1), 5-17.

Helms, J. V. (1998). Science—and me: Subject matter and identity in secondary school science teachers. *Journal of Research in Science Teaching, 35*(7), 811-834.

Johnson-Laird, P. N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.

Kavanaugh, A., Carroll, J. M., Rosson, M. B., Reese, D. D., & Zin, T. T. (2005). Participating in civil society: The case of networked communities. *Interacting with Computers: Designing for a Civil Society, 17*(1), 9-33.

Kavanaugh, A., Carroll, J. M., Rosson, M. B., Zin, T. T., & Reese, D. D. (submitted). Community networks: Where offline communities meet online.

Kavanaugh, A., Reese, D. D., Carroll, J. M., & Rosson, M. B. (2003). Weak ties in networked communities. In M. Huysman, E. Wenger, & V. Wulf (Eds.), *Communities and technologies* (pp. 265-286). Amsterdam, The Netherlands: Kluwer Academic Publishers.

Kavanaugh, A., Reese, D. D., Carroll, J. M., & Rosson, M. B. (in press-a). Using community computer networks for social and civic participation.

Kavanaugh, A., Reese, D. D., Carroll, J. M., & Rosson, M. B. (in press-b). Weak ties in networked communities. *The Information Society*.

Kim, B. (2004). *Rethinking cognitive tools: Its constructs, design, application, and research.* Unpublished dissertation, University of Georgia, Athens.

Kim, B., & Hay, K. E. (2005). *The evolution of the intellectual partnership with a cognitive tool in inquiry-based astronomy laboratory.* Paper presented at the 2005 Computer-Supported Collaborative Learning conference, Taipei, Taiwan.

Kuhn, T. (1993). Metaphor in science. In A. Ortony (Ed.), *Metaphor and thought* (2nd ed., pp. 533-541). New York: Cambridge University Press.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lightman, A. (2005). *Sense of the mysterious: Science and the human spirit*: Pantheon.

Lindner, R. W. (1997). *Understanding educational research: A handbook*: Unpublished manuscript, Western Illinois University.

Linn, M. C., Davis, E. A., & Bell, P. (2004). *Internet environments for science education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Massachusetts Institute of Technology. Adjunct professor of humanities. Creative writing, physics. Retrieved June 10, 2005, from http://web.mit.edu/afs/athena.mit.edu/org/h/humanistic/www/faculty/lightman.html

Mead, M., & Métraux, R. (1957). Image of the scientist among high school students: A pilot study. *Science, 126*(3270), 384-390.

Merriam-Webster. (1993). *Merriam-Webster's collegiate dictionary* (10th ed.). Springfield, MA: Merriam-Webster.

National Center for Student Aspirations. Retrieved June 2, 2005, from http://www.studentaspirations.org/
Nussbaum, E. M. (2004). The effect of goal instructions and need for cognition on interactive argumentation, *Contemporary Educational Psychology* (pp. 1-29): Science Direct.
Nussbaum, E. M., Sinatra, G. M., & Poliquin, A. (2005). The role of epistemological beliefs and scientific argumentation in promoting conceptual change. Paper presented at the annual meeting of the American Educational Research Association (AERA). Montreal.
Pajares, F. H. (2001). Response format in writing self-efficacy assessment: Greater discrimination increases prediction. *Measurement and Evaluation in Counseling and Development, 33*(4).
Reader's Digest. (1996). *Reader's Digest—Oxford complete wordfinder*. Pleasantville, NY: The Reader's Digest Association.
Reese, D. D. (2003a). *Metaphor and content: An embodied paradigm for learning*: Unpublished doctoral dissertation, Virginia Polytechnic Institute and State University.
Reese, D. D. (2003b). Trees of knowledge: Changing mental models through metaphorical episodes and concept maps. In R. E. Griffin, V. S. Williams, & J. Lee (Eds.), *Turning trees: Selected readings*: International Visual Literacy Association.
Reese, D. D. (2004, April). *Assessment and concept map structure: The interaction between subscores and well-formed mental models.* Paper presented at the American Educational Research Association, San Diego, CA.
Reese, D. D. (2005, July). *Developing sound metaphors for science education.* Paper presented at the Gordon Research Conference: Visualization in Science Education, Oxford, England.
Reese, D. D. (October, 2003). PFNET translations: A tool for concept map quantification. In M. Simonson (Ed.), *Proceedings of selected research and development papers presented at the national convention of the Association for Educational Communications and Technology* (Vol. 1). Anaheim, CA.
Reese, D. D., & Coffield, J. (2005, February). *Just-in-time scaffolding: Engineering sound instructional metaphors.* Paper presented at the International Conference on Technology, Knowledge, and Society, University of California, Berkeley.
Renninger, A., & Hidi, S. (2004). *Interest and text processing.* Paper presented at the American Educational Research Association, San Diego, CA.
Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher, 34*(4), 14-22.
Sternberg, R. J. (1991). Giftedness according to the triarchic theory of human intelligence. In N. Colangelo & G. A. Davis (Eds.), *Handbook of gifted education* (pp. 45-54). Boston: Allyn and Bacon.
Sternberg, R. J. (1997). *Successful intelligence: How practical and creative intelligence determine success in life*. New York: Penguin Putnam.
Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, MA: Cambridge University Press.

Appendix: Consultants

The Classroom of the Future inspiration hypotheses and lab teams have identified two education research experts to serve as the consultants necessary to ensure that the experimental design and data analysis of the Inspiration Challenge and the informal event are robust and sound enough to withstand the rigors of today's standards for high-quality empirical educational research. The first, Dr. Barbara Schneider, is highly regarded within the United States as a key leader in education research quality, policy, and techniques. Her interests and expertise align with this year's inspiration construct. The second, Dr. James B. Schreiber, is a statistician at Duquesne University with expertise in hierarchical linear modeling, which is a critical component of the inspiration research.

Dr. Barbara Schneider

Dr. Barbara Schneider is coauthor of *Becoming Adult* (Csikszentmihalyi & Schneider, 2000), which reported results of a longitudinal Sloan Foundation study about teenagers and productive life and career choices. Schneider serves as a prominent expert for the National Research Council and the National Science Foundation (http://www7.nationalacademies.org/core/Barbara_Schneider_Bio.html). Classroom of the Future researchers will consult with Schneider as they continue to develop instrumentation to measure the inspiration hypothesis. For example, researchers will discuss the overlap between the Classroom of the Future inspiration hypothesis development and instrumentation and Schneider's Sloan Foundation study of teenagers and parameters that help learners to make productive choices in preparation for adult careers and lifestyles. Schneider's remarks during her committee's report for the National Research Council: Advancing Scientific Research in Education (http://www7.nationalacademies.org/core/Focus_of_CORE.html) confirmed that Schneider's recommendations for scientific educational research aligned with current Classroom of the Future procedures for developing the inspiration hypothesis.

Schneider has co-developed research techniques for measuring young people's flow (a measure of engagement and proxy for inspiration), quality of experience, and career orientation. We have hired Dr. Schneider and her team to adapt her instruments and analysis techniques specifically to our inspiration hypothesis.

Dr. James B. Schreiber

The Inspiration Challenge will require the use of hierarchical linear models to analyze our data because we are randomly assigning participants at the classroom level. This makes the data correlated. It has the potential to affect the statistical results unless the proper statistical technique, called hierarchical linear modeling (HLM), is used to correct for the correlations. HLM is an advanced statistical technique in which no Classroom of the Future employee is proficient. Therefore, we have located a statistician expert whose specialty is HLM to train the researchers and to oversee our analyses.

Dr. Schreiber's expertise is demonstrated by his current appointment as an editor of two technical research journals for which he reviews manuscripts that use HLM.

The following are highlights of his career and expertise:

- Chair,Mathematics Department, Seton High School
- Instructor of Advanced Mathematics (Calc/Diff Eq), Seton High School
- M.S. in research methodology/statistics, Indiana University (Bloomington, IN)
- Ph.D. Cognition/Learning, Indiana University (Bloomington, IN)
- Dissertation title: Multilevel modeling and TIMSS
- Recent HLM publication (2004): "Review of Multilevel Modeling and Multilevel Studies in the Journal of Educational Research," published in The Journal of Educational Research.

- Executive editor: The Journal of Educational Research, 2005-2008
- Executive editor: The Journal of Experimental Education, 2005-2006
- Invited address for the National Reading Council, December 2005, Topic: Multilevel modeling and reading achievement: Issues and Opportunities.
- Evaluator of national federally funded grants (while at the Indiana Center for Evaluation). Plus one of the people involved with the Cleveland Tutorial Program (aka, Cleveland Vouchers) while at the center.