Creativity and Cognition

This paper is mainly dedicated to surveying the methods and philosophies proposed at the Creativity and Cognition conferences, and similar events. The topics vary greatly around the conference, so the scope of this paper will mainly look at the submissions dedicated to the role of creativity at the educational, collaborative, and individual level. Some papers within the conference led me to papers outside of the conference; so many related papers make their way on to here. This survey approaches the lessons on creativity as it can be applied to the software development process, but it also investigates the lessons other disciplines may offer to foster creativity.

Creativity at the individual level

The first creative process theories surfaced in literature during 1926. The process was published by Wallas, and it consisted of four phases: preparation, incubation, illumination, and verification (Wallas 1926). The first stage, preparation, involved researching a particular subject. During this period, a person investigates all areas related to the subject so that they can form a basis for the solution. The next step is the incubation phase. During this phase the person places the subject out of his mind and lets it rest in his subconscious. This phase continues until an epiphany signals the coming of the illumination phase. The person has a sudden stroke of insight that may or may not be true. The final phase is dedicated to checking that the insight gained during the illumination phase is correct. If not, it’s back to the incubation phase. Modern creativity has matured beyond this simple model, but these phases were the basis for emerging creativity theories at the time.

The paper by Andy and Eamonn gives a great summary of the prevailing creativity theories that followed the Wallas model. The major theories agreed, which were theorized by Olbon, Amabile, and Schneider, that creativity begins with a planning phase. They diverge in their philosophy on what happens during the incubation period, where some argue that the unconsciousness begins making logical connections, while others say that the connections are
made consciously. All include an idea generation stage (Andy and Eamonn 2005). Shneiderman believes that the majority of literature on creativity can be classified into 3 categories: Structuralists, Inspirationalists, and Situationalists (Shneiderman 2007). Structuralists believe they can follow a set of methods to arrive at a creative solution. This method is similar to the method proposed by Wallas, as it has a preparation, incubation, illumination, and verification stage. Shneiderman reports some success with the classic method, but many have deviated slightly from it with great results. Another type, an inspirationalist, tries to break away from the norm in order to receive inspiration. They are big fans of the incubation phase, believing that the right atmosphere may trigger the eureka moment they were waiting for. Inspirationalists often utilize sketching software to quickly record ideas, as well as mind mapping tools. Situationalists, on the other hand, seek to understand everything about a creative person, and figure their relationships with those around them. They also seek to understand what roles rewards play into their motivation (Shneiderman 2007).

In 2005, a group of influential characters in creativity literature gathered for the 2005 work on creativity tools. The purpose of the workshop was to converge creativity research in several disciplines into one focused effort, encourage precise research methods, and increase the ambitiousness of research programs. Up until the day this workshop was held, research in creativity has been focused on the creative individual and increasing the native creative capacity of that individual. This conference aims to shift the focus away from creating a creative individual, and instead creating software tools that support creative activities. The distinction is subtle, but the difference lies in that research in the former attempts to guide people into become a creative person, while the latter focuses on creating

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<td>2. Low threshold, high ceiling, and wide walls.</td>
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<td>3. Support many paths and many styles.</td>
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<td>4. Support collaboration.</td>
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<td>5. Support open interchange.</td>
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<td>6. Make it as simple as possible—and maybe even simpler.</td>
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<td>7. Choose black boxes carefully.</td>
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<td>8. Invent things that you would want to use yourself.</td>
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<td>9. Balance user suggestions with observation and participatory process.</td>
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<td>10. Iterate, iterate—then iterate again.</td>
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(Ben Shneiderman 2006)
tools that would shine only while a creative person is using them. An example is a mind map tool, which looks impressive when a good amount of divergent and convergent brainstorming goes on.

The conference highlighted the three important characterizations Mihaly Csikszentmihalyi made for understanding creativity. Csikszentmihalyi gathered these after interviewing 91 creative minds. The results are as follows:

1. **Domain (e.g., mathematics or biology)** "consists of a set of symbols, rules and procedures."
2. **Field:** "The individuals who act as gatekeepers to the domain ... decide whether a new idea, performance, or product should be included."
3. **Individual:** Creativity is "when a person ... has a new idea or sees a new pattern and when this novelty is selected by the appropriate field for inclusion in the relevant domain."

(Csikszentmihalyi 1996)

Csikszentmihalyi also wrote the book Flow the following year. No one has claimed a connection between flow and creativity, but it was reported that those who were on a creative streak entered a state of flow.

In a separate document a few years after Csikszentmihalyi wrote Flow and Creativity, Shneiderman developed a four-phrase framework that could be used to support the creative process for information technologies interfaces. The four phrase process is: 1) Collect, 2) Relate, 3) create, and 4) donate (Ben 2000).

The framework is an extension of the principles brought by Csikszentmihalyi from his book. The principles first loosely translated into what Shneiderman called the four genex’s: new knowledge is built on old knowledge, powerful tools can support creativity, refinement is a social process, and creative work is not completed until it is disseminated. After a few years, the genex eventually became the four-phase process mentioned in the previous paragraph. The entire process was changing from what it was before. The World Wide Web allows people to collect information better than they have ever done before. The goal of the genex framework was to aid creativity by reducing the distraction of bad interface on the World Wide Web.
Goldschmidt, herself, set out to create a metric to forecast the quality of an idea just by analyzing the process that formulated the idea. Goldschmidt suggested that the best innovative ideas were closely linked to several existing ideas (Gabriela Goldschmidt 2005). Existing methods of enhancing creativity focused on brainstorm sessions that would generate fresh ideas. Goldschmidt, instead, places emphasis on collecting resources before creating links between ideas. Goldschmidt did this through her research with Linkographic diagrams that highlighted the links between ideas. Judges decide if two nodes have enough in common to merit a link set links in the diagram. Going along with the theory that the more links an idea has the more important it is, nodes that have above a certain amount of links can be considered critical or important elements in a diagram.

In analyzing a critical link, we find that there are two different types. A forward link that has its critical elements concerned with a forward motion, and a node that is concerned with links that connect to previous moves or ideas (Gabriela Goldschmidt 2005). Truthfully, at this point the paper becomes difficult to follow, but Goldschmidt’s notion that a good idea should build heavily on past ideas does sound right intuitively. However, it should undergo third party inspection.

Another aspect of creativity on the personal level is sketching. Sketches of Thought, by Vinod Goel, provides a strong argument for sketching in the creative process. Sketching is the most natural and rapid tangible form to communicate or express abstract ideas (Goel 1995). Sketching figures lessens the cognitive load on the mind since sketches act as an index to previous thoughts. A sketched toaster figure triggers a person to recall the general feelings that they had while working with the figure, allowing a person to tackle a multitude of information without juggling ideas.

An individual is much likelier to attempt alternatives while sketching than writing or using another tool. A sketch based interface, whether paper or an electronic sketch tool, allows the individual to have a low commitment to what they are creating. An individual is much likelier to experiment and attempt alternatives when they are working with low fidelity models (MW Newman 2003). CAD tools force the user to make a decision by sizing boxes, moving through
menus, and committing actions. Sketch motions are much soother and quick. Also, when working with paper, the user knows that the paper will behave exactly as they expect it to. Users know they must deal with a multitude of possible problems when their tool is software based.

Sketching has two modes of transitions. The first mode is a vertical transition where the sketcher shifts scope. For example, they can be working on the architecture of a campus, and the sketcher begins filling out the details to the humanities building. He would perform another vertical transition again if he return to drawing abstract figures around the building. The other type of transition is a lateral transition, where the sketcher switches topics. For example, the sketcher is thinking of different styles of buildings he could try, and switches from the current sketch of the building to a different canvas and attempts another style. A good designer will have a roughly equal number of vertical and lateral transitions in the initial phases of development. As decisions are solidified, the number of transitions becomes heavily vertical.

Sketching on a paper and sketching on the whiteboard are two different phenomena. When I first met with Kumiyo Nakakoji, she made it a point that the expectations and tasks a person has for a whiteboard is not the same as an individualized paper. On a paper, people may focus on the details and produce several different sketches of one figure until they’re content. A whiteboard is generally a collaborative tool, and drawing takes slightly more effort than paper. Typically, people use the whiteboard for either list making, or drawing rough figures for reference. Often the figures and some times the list are illegible, but they have meaning within the conversation since the artist may refer back to the figure as a physical point of reference.

**Creativity in collaboration**

In the recent years a good deal of research has gone into investigating creativity in a group setting. A greater number of papers concerning using technology to support creativity in a collaborative setting have been appearing in conferences. Before investigating the impact of technology on group creativity, the subject of collaborative creativity without technology should be considered first.
Osborn, a creativity researcher in the mid 50’s, drew a comparison between a nominal group, which is a group of individuals working individually until they combine their results afterwards, and a real group, which is a group of people working collaboratively the entire time. Osborn strongly believed that a real group would always generate more and better ideas than a nominal group. In other words, the resulting creativity of a single group is greater than the sum of its parts (Osborn 1953). Osborn believed that quantity brought quality in terms of creativity. He believed that a real group could cause an individual to generate upwards of double the novel ideas that he could on his own. His idea was largely accepted until another individual challenged his assertion. A later study proved that a nominal group provides a better creative result when brainstorming separately, than a real group brainstorming together (Taylor 1958). The actual case was that the sum of the parts was not greater than the whole. In fact, disjoint groups produced considerably more novel solutions than collaborating groups. However, a study a half a century later refutes this claim and identifies a set of conditions that would lead to different results if addressed.

A study published in 2005 claimed that the empirical evidence produced by Taylor was due to production blocking, evaluation apprehension, and social loafing (Andy and Eamonn 2005). When a group holds a discussion, only one person can speak at a time. This forces all others to hold back their ideas until a proper time arrives to raise their issue. Innovative ideas that are held back may be forgotten or dismissed, reducing the number of novel solutions produced by that group. Group participants may also ignore group activity while they rehearse their idea mentally. Andy and Eamonn propose that members should write their ideas during their creativity sessions and distribute their ideas later on. Another threat is that group members may suffer evaluation apprehension. They may feel like their group members are judging them, or that their ideas are not mature enough to announce to the group. Andy and Eamonn inferred that people become apprehensive when in the presence of their peers, or when faced with a controversial topic (Andy and Eamonn 2005). Their nervousness reduced their capacity to think divergently. Andy and Eamonn suggest that an anonymous means of distributing ideas be
created. However, this removes accountability for items. This assertion has not been tested yet, but I do not see this suggestion working well since it removes ownership of ideas. Lastly they suggest that social loafing is a large factor. When members of the team perceive their contribution is not significant or not needed, some members may not put as much effort into the activity. They propose to avoid this by assigning accountability to ideas, but this directly contradicts the solution to the second observation.

Andy and Eamonn’s commentary on group distractions sets the stage for technology to enable group participation in a discussion and increase accountability. The TEAM STORM software, produced at Illinois University, performs the job nicely. It is a network-based tool that allows a group of people to share ideas while maintaining a private workspace. Each user has a tablet to draw their ideas in a personalized workspace. Each tablet also has access to a community workspace where participants can share diagrams and collaborate with one another in real time (Joshua, Erik et al. 2007). This allows participants in a group creativity session to privately develop ideas until they are ready to share them with the group. The TEAM STORM environment allows team members to have a brief incubation period while they privately work near one another. Members can then reflect on not only their designs, but the designs of their team members as well. The program functionality address the issues mentioned by Andy and Eamonn. The Calico project at UC Irvine (Mangano 2007) has a similar mechanism to collaborate work between users, however collaborative aspect of Calico is limited to student-teacher interaction. Calico Classroom edition has a client application that students use to draw, and a server application that monitors
students’ sketches in real time. Unlike TEAM STORM, where team members have the power to share their designs, Calico gives one professor control to enlarge a student’s screen to share with the class or share an existing diagram with students. Calico enforces a measure of accountability by enabling a third party, in this case the professor, to observe their progress. Since Andy and Eamonn reported mixed findings of collaborators suffering from evaluation anxiety with remote judges, students would hopefully not be affected.

Another creativity system, developed at Ludwig-Maximilians-Universität Munich, takes a different approach for collaboration. This system uses a large touch screen horizontal display that permits users to create Post-It Notes. Once created, users can mark up the post it notes, move, and rotate them. Additionally, notes can be grouped in to clusters, and relationships can be created between clusters. Later, notes are clustered, supporting a convergent creative process. Although the paper supporting the group’s effort does not state it, the methodology is similar to lateral and vertical transitions described by Vinod Goel (Goel 1995). The Post-It Note interaction model is surprising similar to the scrap interaction model possible within Calico. However, their context varies slightly so they serve different purposes. Direct interaction aside, this system differs from TEAM STORM in a major way in that it trades a networked interface for a face-to-face collaborative model (Otmar, Lucia et al. 2007).

The team from Illinois put the Post-It Note functionality to the test when it conducted a brainstorming session aimed at stimulating divergent thinking. User testing found that this table did not increase productivity over a regular paper and white board, but the results were extremely close. The study demonstrated that the face-to-face, tabletop interaction did not suffer from the three defects identified by Andy and Eamonn. The creators of the device firmly believe
that the social interaction from the face-to-face model will yield long term benefits through team building, which will outweigh the penalty of working in a real group.

**Creativity in Education**

An effort has been made to investigate creativity in an educational setting. Creativity in education has the old fashioned goal of fostering the creative spirit within a person. This is in contrast to the new goals established in the creativity workshop in 2005, which attempted to shift the focus of creativity tools to supporting creativity, rather than fostering it.

Several techniques have been proposed to increase the creativity for the classroom. One proposed technique is the Creativity Surprise Model (CSM). CSM identifies two types of thinking in the creative process, divergent and convergent thinking. The method focuses on improving the former by shocking a person out of their comfortable perception of reality. The more a person can be surprised, the greater the degree their ability to think divergently is enhanced. The CSM process begins by presenting an every day object to a person and asking them to perform an average activity. However, the every day object is altered in an unconventional way that distracts a person. Their level of distraction can measure the degree of surprise. A study that investigated CSM presented children with a jump rope and asked them to count the number of times their partner jumps in a minute. The activity was given a twist by modifying the jump ropes so that they played music and created images while a student used it. The results of the study showed that the students were much more novel, but they tended to focus around specific answers. The answers became more unique, and the students began to challenge the role of everyday objects. (Su, Adrian et al. 2007).
Another study conducted at CMU attempted to identify parameters and principles for organizing and conducting creative activities. The study proposes a Leonardo model of participation in which participants in a multidisciplinary project become knowledgeable in disciplines outside their expertise. While conducting the study with the mentioned approach, three patterns of activity emerged: owning the problem, design and the play instinct, and building tools to make things (Ellen Yi-Luen and Mark 2007). In the owning the problem approach, designers were part of their target audience. Designers who utilized their own products became invested in the design, and had an overall better design. The creator of emacs had the goal of creating a better environment for coding, serving his own interests. In the tinker, design, and play instinct approach, designers were encouraged to experiment and build solutions that may not have necessarily be related to their original problem. This type of approach is in sharp contrast to the user-centered approach where the problem is initiated with a set of guidelines in mind. The user-centered approach attempts to avoid unnecessary exploration, which could be viewed as a waste of time. However, an innovative solution may be overlooked. The final pattern of building tools to make things allows the designer to open up new design spaces by providing a new environment to tinker. It was interesting to note that this pattern sounds similar to the second pattern, but this pattern increases a designer’s ability to apply the second pattern.

A trend emerged between the participants with an engineering background and those with a design oriented background in the above study. Those with an engineering background readily proposed a solution to a given problem. Engineers preferred a well-structured task with strict requirements rather than an open-ended solution. Designers, on the other hand, approached the problem with a totally reversed perspective. They considered a multitude of alternatives before settling on any single one, and often ignored strict requirements in their solution (Ellen Yi-Luen and Mark 2007). Designers who participated in the study stated that it was engrained in their educational training to always consider alternatives before approaching an issue. Engineers, conversely, pick a solution that best fits a problem from their repertoire. This
may be an important lesson for the UCI informatics department if its goal is to produce graduates who consider themselves designers rather than engineers. Perhaps the classes should be structured to include activities that emphasize the exploration of alternatives before committing to any one approach.

As a closing example for education, it is interesting to look at the difference in approach that teachers have with grown children and kindergarten children. The schools of today put a lot of focus on memorizing terms and not enough emphasis on raising the creative thinkers that are rewarded in today’s businesses. Schools should not expect to raise the next Einstein, but they should at least be teaching kids to look at modern ideas in a more creative way. (Mitchel 2007) There was a time in the educational system when children were encouraged to experiment with everyday objects, but those days ended when they graduated from kindergarten.

As children age, they need more sophisticated tools to expand their imagination. To fill this void, tools like Cricket (a small programmable robot) and Scratch have emerged. Mitchel created Scratch to encourage students to innovate and tinker. Scratch gave a new perspective to educational software. Traditional electronic educational software focused on delivering information to the student rather than allowing them to create. Scratch emphasizes the activity of making, and allows the student to reflect on what they have done. It was one step in the right direction.

**Measuring Creativity**

An interesting lesson to take away from this survey is the methods in which the groups measured their subjects’ creativity. Creativity is highly susceptible to a subjective measurement if not done right, so I am curious what lessons I can take away from the observed studies to conduct my own study.

The creativity workshop in 2005 dedicated a section towards establishing a measurement for creativity, although they did not settle on any standards. Creativity is a difficult concept to measure since it could qualify as a nonfunctional requirement. The workshop implies that purely
objective measures for recording creativity are difficult since situations between studies vary greatly. The final decision was to gather large amounts of data from several studies to create a new method for measuring creativity (Ben Shneiderman 2006). This method sounds slightly odd in my opinion. In studies done in the psychology discipline, they have used a meta-analysis to create meaningful data from several small studies that were too small to be statistically significant. The proposal in this section from the conference sounds like a far off wish. In my opinion, it would be better to look at results on a trial-by-trial basis until a good method appears.

The study on the Creativity Surprise Model, which was done after the conference, had a convincing approach to measuring creativity. The writers of the study applied the Torrence Test for Creative Thinking (TTCT). This study focuses on testing four attributes: Fluency, Flexibility, Originality, and Elaboration (Torrance 1974). Fluency was the number of meaningful answers. Flexibility was the number of different categories of responses. Originality was the number of statistically unlikely responses. Lastly, elaboration was the amount of detail in the response. In the study of the Creativity Surprise Model, the test involved asking the children to name several types of items. The results of the study was noted in the Creativity in Education section, but was also interesting to note in the study that they measured the surprise of the children by asking them to perform a normally mundane activity, and measure how much they were distracted away from it.

The study performed by Warr and O'Neil proposed to use the creativity testing method created by Gough, the Creative Personality Index (CPI). This creativity index had a set of 18 adjectives that were considered positive creative attributes, while 12 adjectives were negative, noncreative attributes. Checking off all adjectives that describes yourself would create a personality profile that would describe a person’s creative ability (Andy and Eamonn 2005). Other psychologists refuted the validity of CPI, so the measurement was considered generally untrustworthy.

The study involving the Post-It Note metaphor followed a system of measurement that seemed like the TTCT measurement, but it did not mention the TTCT method. They observed
novel ideas, ideas built on older ideas, ideas resulted from watching another write down an idea, and ideas that resulted from talking about an idea (Otmar, Lucia et al. 2007). This experiment measured fluency and originality in its test subjects, and neither seemed to have shown a great discrepancy between a digital medium and a regular medium.

**Concluding Thoughts**

Creativity has become a vibrant topic in the computing world. Its following received a large boost in the mid nineties after Csikszentmihalyi published Creativity and Flow. The movement gained momentum and the conference on Creativity and Cognition began in 1999. The movement is also picking up steam since digital sketching hardware is becoming accessible, which enables programs like TEAM STORM, the Post-It Note program from Germany, and Calico to function to their full intention. Sketch tools are becoming increasingly cheap thanks to advances in cost effective technology (Han 2005).

As the opening of the creativity workshop of 2005 said, studying creativity is a dangerous endeavor since it may not yield any results, but if the research is successful the pay off will be worth it. Schools have traditionally focused on creating an atmosphere that does not encourage people to think outside of the box. This is true for primary, secondary, and I have even colleges. The undergraduate program for ICS program is structured in a manner that focuses on delivering information to the students, rather than encouraging students to explore. That isn’t to say that an exploratory approach is necessarily the best method for teaching students, this requires a lot of time and effort from the professor and may not be appreciated by all of the students. However, a few classes should be available that are not project courses that are engaging. The students would appreciate it.


Han, J. Y. (2005). Low-Cost Multi-Touch Sensing through Frustrated Total Internal Reflection. the 18th Annual ACM Symposium on User Interface Software and Technology.


