Enhanced Creativity and Problem Solving: An Interdisciplinary Approach

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ABSTRACT

The University of South Alabama has established an interdisciplinary course to expand and foster creative thinking and problem solving using appropriate and readily available technology. This creative approach when linked with an aspect of technology will appeal to and benefit many diverse student populations. This educational approach to encourage creativity incorporates: design experiences, technology skill development by practical hands-on events, an open-ended challenge to solve, multiple documentation and presentation expressions of the work, and evaluation of work for enhancing creativity and problem solving. This course was structured to take advantage of a multi-disciplinary teaching and learning environment. The course is being team taught by faculty from the disciplines of Computer Science, Psychology, and English. The targeted student population initially consists of Computer Science majors and members of the Honor's College (any major). Based on the results of this work the course would be open in the future to any major. The role of each instructor is to provide guidance on how each discipline contributes to the creative process of solving an interesting and challenging problem. The aspects of the disciplines considered include: the narrative or descriptive documentation of the process (not just the usual software documentation), an understanding of the relevant cognitive issues needed to address the problem, and the technology needed to solve the problem. The challenges consist of a task that is of wide appeal not only to the students solving it but a larger audience who might benefit from the knowledge of the solution. Sample challenges include problems involving robotics or game development which can be easily understood and visually appealing to all students involved.

Keywords: CS Education, Creativity, Interdisciplinary Problem Solving, Robots

1. OVERVIEW

The role of creativity is critical to any academic curriculum and should be central to that of Computer and Information Sciences (CIS) [1]. The three disciplines forming the core knowledge for the course were: Psychology, English and Computer Science. From Cognitive Psychology the salient aspects of creativity and problem solving are discussed. Relevant strategies to solve a problem and techniques to expand the students' vision of how a solution evolves were considered. The role of storytelling and effective narrative is considered from the discipline of English. So often computing majors view writing as a terse, factual recount of the static details of project development. Finally, technology skills are enhanced to facilitate exploration of solutions to open-ended, real-world challenges. Each discipline specific concept is presented at the appropriate time. This blending of the disciplines further established the interdisciplinary learning environment. Associated activities from each discipline reinforced a variety of problem solving attributes from current or previously mastered concepts. Hence, the course was not simply five weeks of discrete psychology instruction followed by five weeks of English and then five weeks of CS.

The course targets two populations: (i) CS majors at and above the sophomore level, and (ii) Honors students at the sophomore or junior level. The anticipated benefit to both groups was to increase their awareness and skills necessary for creative problem solving. Although the immediate domain of application is using technology, the implications of enhanced creative problem solving should transfer to any domain or discipline of study. This awareness encompassed the three area of study mentioned above – Psychology, English and Computer Science. This likewise portrays that effective and creative problem solving is not performed in isolation but draws upon many and diverse disciplines. It is hoped that this early and explicit application of these concepts will be recognized as a skill and model to employ during the remainder of their college studies and as they engage in their careers.

This course was treated differently by each of the above target student populations. For the Honors students this course was treated as an Honors Seminar in computing (CIS). The analysis and design issues as well as the implementation of the solutions met and exceeded the current technology component in the CIS courses used for Honors student presently. The added benefit of the creativity and problem solving certainly provided a very exciting and challenging computing course for this talented student population. For the CS majors this course was treated as either a social science or humanities course. The main benefit for the CS majors was the extension of their existing skills to a new area – robots, and the broader vision of open-ended challenges that might be solved using this technology. It is that cognitive (social science) or expression (humanities) aspect of the solution, not the factual details, which was insightful for CS majors.

2. PROBLEM STATEMENT

Current computing courses often lack creativity and focus on the same usual activities. This lack of creativity might cause many students to feel a lack of connection to real-world situations by the computing discipline. Lacking this connection, students cannot see or understand the broad impact of computing. It is this disconnect between the users of technology and the development of technology that might have contributed to declining enrollments in the computing disciplines. Also, computing courses often tend to be isolated in their view of practical applications and contact with other disciplines. The curriculum model identifies outcomes that require broader views and visions in solving the complex problems encountered. The curriculum also explicitly calls for the ability to interact and communicate effectively with a wide audience.

To combat these problems our course defines an educational approach that encourages creativity. This learning environment is hands-on and relies on a variety of cognitive models. The program implementation is not the only expression of the solution but a variety of stories and narratives are necessary to describe the challenge and solution. A blend of skill building and open-ended challenges are assigned to exercise the cognitive processes of the students. A cognitive-based assessment instrument is employed to measure the effectiveness of the activities used in the course. A reward system is employed where solutions judged most creative and effective are highlighted and showcased. By the accomplishment of these activities, we will answer the general questions of how to improve the understanding of the creative process in the context of the computing discipline and provide an innovative approach to computing education. Specific assessment instruments were developed to measure the learning experience of the students. Those assessment instruments will be discussed later in the evaluation section.

3. COGNITIVE PSYCHOLOGY and PROBLEM SOLVING

Cognitive Psychology and CIS have been collaborative partners since their inception. It is the goal of the first part of this course to provide students with a brief historical overview and background in cognitive approaches to problem solving. Students are presented a series of lectures and demonstrations involving hands on problem-solving exercises that expose them to the dominant theories of problem solving, as well as the extant paradigms for viewing classifying common problems. Once students have learned about and attempted to solve some common types of problems encountered in everyday life and in the engineering environment, they construct narratives that provide a context to these abstract problem solving skills. Students advance to incrementally more difficult problem types, and to more difficult problem exemplars within the problem types, to build confidence and skill in general problem solving strategies.

The first part of the course consists of specific instruction in the cognitive psychological research in the areas of problem solving. Prominent theories and results from empirical investigations was presented [5], with each key concept being illustrated by a *key problem.* The key problems are designed to allow students to discover the nature of the cognitive psychology concept through brain-storming, small group collaboration, and an example-based methodology [3]. Here, students are not told of the “correct” or traditional answer to a problem until after they have created, refined, and presented their solution to the class. A lab session occurs in which students compare and contrast their solutions and are encouraged to provide constructive feedback to each other about the strengths and weaknesses of their solution. The workshop culminates in the creation of a written narrative or other, appropriate written product.

Students are introduced to key concepts from the Cognitive Psychology of Problem Solving. The unit begins with introducing problem solving as a domain of thinking, and then we discuss some of the basic cognitive components of problem solving. We center much of the discussion on Newell and Simon and conceptualization of problem solving as a sub-type of general information processing. The role of short term working memory, and of encoding into long-term memory are discussed. Based on this, we introduce our first key problem; *Key Problem 1*: The structure of problems affects memory search. In this exercise, we present them with a series of increasingly complex, ambiguous scenarios. These scenarios, based on Johnson et al. [4], allow students to attempt to solve problems with a relatively large amount of detail. The addition of a central theme, or narrative, allowed the minimization of cognitive load. For example, students were orally presented with a scenario about doing laundry that has all of the task-specific nouns removed, such as socks, or detergent.

The students are asked to remember as much as they can about the story, and to recall it after a 30 second delay. One half of the class is told that it is about doing laundry, while the others were told nothing. The scores for all students are tallied, and compared, and are used to open up a discussion about what was important about knowing what the story was "about." This exercise culminates in the students writing their own ambiguous scenarios, and presenting them to each other for practice. Students discover that a central, organizing story is a powerful tool for encoding, processing, and solving a particular problem with maximal cognitive efficiency. We then discuss the relationship between inductive and deductive modes of thinking.

We continue on to discuss **w**ays of classifying problems, such as problems of arrangement, inducing structure, and transformation problems. Our Key Problem 2: Functional Fixedness and escaping from confinement illustrates the idea of the importance of fluency in generating possibilities for problem solving, Functional fixedness is a specific type of cognitive limitation on problem solving known as a mental set, in which individuals fail to recognize uncommon uses for objects. Students are told that there is a person in a small room with a coat hanger, a shower rod, a butter knife, and a power outlet. They are told to think of as many uses for these objects as possible. At the end of this phase, students share their lists, and it is determined whether any of the lists contain interactions between objects. At this point, students are asked to make up a story about the person in the small room who has a goal of leaving that small room, but cannot, because it is locked. Students then go through the process of creating a background scenario, and devising ways that the objects can be combined to permit escape from the room. Perhaps the person will be a criminal trying to escape from jail, or a man locked in his office, or bathroom. The experience culminates in a formal writing project that develops the narrative of the person trying to escape using the different objects in novel combinations. This exercise provides the background for a robotics exercise where students are required to manipulate some random common objects in order to free a simple robot from a makeshift "prison" constructed by the instructor/

We then move on to Key Problem 3: Analogical transfer using the fortress problem. In order to demonstrate the cognitive psychological concept of problem solving through analogical transfer, we utilize an exercise based on Glick and Holyoak's [2] radiation problem. In this situation, we present a specific problem, and ask the students to produce a straight-forward solution. The problem is described as such, "A large tumor is located in a patient's brain. The doctor wants to destroy the tumor with high-intensity x-rays. However, the doctor needs to prevent the x-rays from destroying the healthy tissue surrounding the tumor. As a result the high-intensity rays cannot be applied to the tumor along one path. However, high-intensity rays are needed to destroy the tumor." Students work in small groups to develop a solution to this problem. Students then share, and constructively discuss each of the solutions between their groups. Students then are presented a story about a fortress located in the center of the country. After reading this story, the students are asked if they can see the analogy between the two problems. Students are encouraged to then write an analogous story to their own solution to the problem, and to create an implementation of this solution using the robots.

4. NARRATIVE COMPONENT

Our writing instruction and assignments build recursively on earlier course lectures and on the assigned individual and group projects to reinforce course content and help students fulfill the learning objectives. To achieve these ends, we ask students to use narrative and storytelling to think creatively about problems and solutions. We think this approach can help students convey the value of their research to a variety of audiences. Our approach is premised on the fact that we tell stories every day to explain to others how and why we believe X rather than Y or to explain how a particular event happened one way under a certain set of circumstances and not another way. Indeed, as narrative theorist Jonathan Culler says, "Scientific explanation makes sense of things by placing them under laws—whenever *a* and *b* obtains, *c* will occur—but life is generally not like that. It follows not a scientific logic of cause and effect but the logic of story, where to understand is to conceive how one thing leads to another, how something might have come about: how Maggie ended up selling software in Singapore, how George's father came to give him a car" (pp 83-84) [2]. Given this reliance on narrative every day, our students are asked to construct and use stories to respond to in-class experiments and to convey the end-of-semester problem-solving approaches for their respective groups.

Some storytelling exercises build on the lectures on cognitive psychological concepts such as functional fixedness, the mental set detailing the person locked in a small room with seemingly odd objects at her disposal to help make her escape, and analogical transfer and memory search. In all of their narratives, students must identify a problem and the available resources at their disposal; likewise, they must connect the resources to devise a method most conducive to solving the problem. This process is also how a narrative or story is put together. There is the introduction that sets up a conflict, a problem that must be overcome; key elements build or expand the conflict, and other elements/events (a "Eureka" moment or turning point) motivate and shape a character's new understanding, which leads to the problem's resolution (the story's climax and its conclusion).

The foundation for the students' narratives is a journal each student keeps. In the journal, students can respond to class lectures and discussions, reflect on their experience of working with their group members on the final project, and generate ideas for initial stories to explain their own and their groups' problem-solving processes. The stories students subsequently construct organize and clarify explanations of how they interacted with and solved information technology problems. To convey the most significant aspects of the problem-solving route that they choose to take, students must reflect on their learning experiences and their audience: What ideas first came to their minds when given an assignment? What difficulties did they encounter in finding a solution? What was fun and why? What worked, what did not work, and why? We know that written reflection helps one internalize information, i.e., take intellectual ownership of complex processes, putting oneself in position to think in innovative ways. Such internalization fosters self-confidence, self-understanding, and clarity of thought.

Students also write an end-of-semester paper that discusses their group project and analyzes their critical thinking strategies vis-à-vis their project goal. Just as the creative construction of computer code requires trial, error, and re-thinking in order to find success, the writing process for the longer paper required drafting and revision, which should help the students better understand what they have accomplished over the course of the semester.

Through writing heuristics that invite students to create narratives that present their problem-solving efforts, our course promotes precisely the kind of active learning that sharpens cognitive and communication skills the students need for explaining to university students and professors as well as K-12 students how they approached their robot assignment or their group project about hurricane relief.

Written assignments include:

- A journal in which students discuss lecture questions and significant ideas raised in class discussion, their experiences working with the robots, and ideas for stories about their problem-solving approaches. Students submit the journal to the faculty on a bi-weekly basis for faculty input.
- An end-of-semester paper about their role and experience in their group project.
- For writing assessment purposes, the students' end-of-semester paper was read and scored by a set of faculty experts in order to evaluate writing improvement in the course.

5. COMPUTER SCIENCE

The CS curriculum targets problem solving as a core concept. What is implicit in all courses of the curriculum could and should at times be more explicit and made readily apparent to the students. Using the basic skills of the computing curriculum, these problem solving concepts are more fully explored. These core concepts were presented using a platform and environment that was engaging and easily mastered. The platform selected is that of the Lego Mindstorms. The simple programming concepts, often mastered by teenagers and most middle school students, were quickly explained to the intended course population. It is anticipated that the CS majors enrolled in this course would serve as technical advisors to the non majors from the Honor's program. However, this is not to excuse those non majors from participating and gaining mastery of these fundamental programming skills. The basic concepts necessary are those of sequential movements and actions by the robot, repetition of actions by the robot and decision making by the robot.

A key concept often overlooked in the effective and efficient development of computer systems is the impact and interdependence of a variety of design issues. This is especially the case when a physical or robotic system is involved. A student software developer seldom gets the opportunity to play an active role in the design or creation of the hardware platform. Even when using robots, a software programmer is constrained by the predetermined limits of the platform. When faced with the task of designing and creating the hardware platform, with the programming objectives in mind, it is anticipated that more opportunity for creativity can result [9]. This in turn allows for a more complete utilization of the hardware features by the robotic device. This hand-in-hand design and development of all aspects of the project is not only more productive, creative and exciting but provides a more realistic view of actual real-world events once they embark on their career.

The computing activities of the course consist of the following tasks:

1. Design and construction of simple wheeled robot.
2. Programming of wheeled robot doing a variety of sequence, looping and decision tasks.
3. Addition of sensors (light, touch, temperature) to wheeled robot.
4. Programming of sensory system.
5. Design and construction of various mechanical platforms – grippers, flippers, pushers.
6. Programming of mechanical platform.
7. Use of IR port for communication.
8. Design and construction of robot/mechanical device that communicates via IR port.
9. Programming of communication protocol.

A series of small and focused tasks are assigned to allow the students to achieve the necessary technical and programming skills. This incremental approach showed the benefit of designing a specific feature of the physical platform that can then be utilized by the appropriate programming techniques. While focused on a specific aspect of design and development, these mini-challenges include an open-ended aspect to encourage a more creative nature to the solutions. A wow factor is considered in each challenge for any solution that takes a more creative approach to solving the problem.

6. FINAL PROJECT ORIENTATION

Once students have considered a series of warm-up problems to practice the process of problem solving and to exercise a degree of creativity, a final and more realistic problem is considered. This final challenge should focus on a serious topic that encourages the students to demonstrate a high degree of creativity in a rather open-ended situation. This challenge should cause the students to draw upon life experiences and engage personal heuristics and strategies that they might refine and expand by this reflective experience. The rest of this section defines and outlines a recent example of the final project to accomplish this goal. Certainly a variety of challenges could be defined based on many factors.

Students at the University of South Alabama are often significantly impacted by severe weather. In the final project, students drew on their life experiences to develop a creative solution to a real-world problem. They were given a final problem of, “A major hurricane has struck the gulf coast. How can you build an intelligent device to assist in beach restoration?”

Hurricane Katrina, in particular, damaged students’ homes, vehicles, places of work, and the campus. Students have a high degree of concern about the frequency and severity of storms in our region, and anxiety about these issues can negatively impact student performance. Providing students with a means to develop creative solutions that will help people deal with storms can provide a channel for students’ nervous energy and anxiety. Additionally, students should feel a high degree of engagement and, similarly, a high degree of motivation to develop creative solutions to the serious problems that they and their family and friends have dealt with on a repeated basis.

7. EVALUATION

The essence of the course is to increase students’ ability to creatively solve problems. Long term benefits of such a program are expected to include a higher interest in being involved with creative projects, and the application of more critical and creative problem solving techniques in graduate school and the workplace.

The course was internally assessed qualitatively and quantitatively using a pre-post design. Students were assessed for their baseline levels of creativity and problem solving across several domains prior to, and immediately following their completion of the course material. The construct of creativity was treated from within the framework suggested by Treffinger, Young, Selby, and Shepardso[8]. This authoritative monograph provides a systematic approach to defining and assessing creativity for educators by identifying four key categories of personal creativity characteristics. The characteristics include:

1) Generating Ideas
2) Digging Deeper Into Ideas
3) Openness and Courage to Explore Ideas
4) Listening to One’s “Inner Voice”

Each of these characteristics explains some unique aspect of what it is to be creative in the broadest context. These characteristics are thought all to be correlated with IQ, but to vary widely within creative individuals, and to be more or less amenable to instruction. The tests that we use below tap into these key concepts both objectively, as in the Torrence Tests of Creative Thinking (TTCT) [6], and subjectively, in our Students Perception of Control Questionnaire[7], and our Approach to Problem Solving Questionnaire [10].

8. RESULTS and CONCLUSION

The course has been taught twice. The initial offering allowed for feedback of students to make necessary modifications. The initial offering also allowed for hardware issues to be addressed and the lab to be properly configured for use by the projects. That initial course also allowed for the creation of the evaluation instruments and a pilot study of use of those and established instruments. Data was gathered and will be collected in a long term fashion to address the on-going research questions. Initial feedback has been extremely positive on the part of the students. They express a high degree of positive experience with the course and each of the activities. The initial results of the final project saw some very unique and creative projects. The time and effort spent by the students exceeded the expectations of the course. In fact, many expressed a desire to continue to work on the projects. Similar feedback occurred the second time the course was offered. A first round of data gathered was analyzed and will be used to make future modifications the next time the course is offered.

The salient features of this course are:

1. Focus on creative and cognitive concepts in CS problem-solving setting.
2. Innovative and multi-disciplinary approach to computing education.
3. Assessment of the educational process, leading to enhanced creativity.
4. External writing assessment of student portfolios by faculty experts.
5. Open-ended challenges, using available technology.
6. Rewards to students who exhibit high levels of creativity.

Table 1 Pre test results

Student	Fluency	Elaboration	Originality
1	4.0	9.0	4.0
2	3.0	5.0	8.0
3	7.0	11.0	15.0
4	2.0	7.0	16.0
5	4.0	13.0	12.0
6	5.0	6.0	11.0
7	3.0	6.0	13.0
8	4.0	9.0	15.0
9	6.0	7.0	10.0
10	2.0	4.0	7.0
11	7.0	14.0	20.0
Overall	4.27	8.27	11.91

Table 2 Post test results

Student	Fluency	Elaboration	Originality
1	4.0	11.0	4.0
2	6.0	7.0	7.0
3	9.0	13.0	16.0
4	7.0	6.0	14.0
5	5.0	17.0	13.0
6	6.0	7.0	10.0
7	7.0	5.0	14.0
8	7.0	11.0	9.0
9	5.0	9.0	13.0
10	3.0	10.0	10.0
11	8.0	16.0	17.0
12	9.0	17.0	21.0
Overall	6.33	10.75	12.33

TTCT Verbal and Figural Thinking Tasks results were tabulated for pre and post class administrations separately for each subject yielding 11 available pre-tests (shown in Table 1) and 12 post-tests (shown in Table 2) (1 student joined the class late). A subset of the test items were selected for use, including ones prompting students to "Improve a Toy," "Imagine if people could teleport instantly," "Add lines to simple figures," and "Add details to shapes." Of the 5 domains commonly scored on the TTCT Figural thinking task, three are reported here: fluency, elaboration, and originality. Fluency changed from 4.27 to 6.23 ($p < .05$), Elaboration changed from 8.27 to 10.75 ($p < .05$), and Originality changed from 11.91 to 12.33 ($p > .05$). Thus the course appears to have helped students to produce more solutions, as well as more developed solutions. Originality was not enhanced directly. The lack of a control group was a limitation, and future offerings of the course will include administering the full TTCT to the class and other groups of honors and non-honors students who are not taking the course to permit comparisons.

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