A Theory of 'Multiple Creativities': Outcomes from an Undergraduate Seminar in Conducting Robots

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Abstract — **In this paper we describe the results of a creativity analysis that was performed on the students enrolled in an undergraduate multidisciplinary seminar entitled *Conducting Robots*. The seminar brought together students from four disciplines with the goal of building non-human systems that would conduct the college orchestra. The setting was a vehicle for teaching collaboration and enhancing student creativity. The data that we collected through tests, surveys, and project evaluations suggests that people can be creative in different ways and they can learn how to increase this creativity.**

Keywords – creativity, computer science, music, robotics, undergraduate education.

I. INTRODUCTION

Computer science has an image problem: computer scientists are perceived as "nerds" who spend their lives in a cubicle in front of the computer, doing things that nobody else understands. Although computers are ubiquitous in our world, and most of us cannot imagine our lives without them, when asked to name some creative activities, people will rarely say computer science. Many students complain that computer science is difficult and boring. It takes a while until they realize that it is actually a very creative domain. Not only can one apply creativity to it, it can also be applied to other fields creatively [9].

Keeping this reality in mind, we designed and taught an undergraduate seminar whose goal was to engage students – majors and non-majors alike – creatively in computer science. We even went one step further and attempted to teach students creativity. In the seminar, undergraduate students majoring in computer science, interactive multimedia, mechanical engineering and music, worked in multidisciplinary teams to develop robotic or animated systems that could conduct an orchestra.

Were we successful? Did our students become more creative? Can creativity be taught and learned? The easy approach to answering these questions would be to measure student creativity at the beginning of the semester, and once again at the end of the semester, and hope for a significant increase between the two values.

Unfortunately our analysis cannot be that simple. Creativity has several different definitions, and, accordingly, several different measures. Many of them are difficult to administer twice. Moreover, the results could be discouraging if we assumed that there is only one type of creativity.

Throughout the four semesters that we taught this course, we concluded that there are multiple types of creativities. The idea is not entirely new. Howard Gardner has proposed a theory of multiple intelligences [3], which he then applied to creativity [4]. He suggested that great creative minds often have relied on different intelligences to manifest their creativity. For example, T.S. Eliot made his reputation through linguistic intelligence, Einstein through logical–mathematical intelligence, while Igor Stravinsky became famous through musical intelligence.

Sternberg sees creativity as a set of multiple attributes, which are not mutually exclusive [11]. According to him, people might show consistent individual differences in processes, domains, and styles of creative thinking.

Dietrich classifies creativity into deliberate and/or spontaneous modes of processing, each of which can direct computations in cognitive and/or emotional structures [2].

Our vision of multiple creativities stems from the results of the student creativity analysis performed during the undergraduate seminar that we developed. This paper describes the seminar, the methodology used to assess student creativity and its results, as well as the creativity types that we observed.

II. DEFINING AND MEASURING CREATIVITY

Theories about the nature of creativity and how to measure it are still actively debated among researchers. Some theories propose that creativity is the generation of imaginative new ideas [8], involving radical innovations. Other definitions claim that creativity can be demonstrated by simply integrating existing knowledge in new ways. Yet other definitions require

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a creative solution to have value or utility [5]. Theories of multiple creativities, such as those in [4], [2], and [11], attempt to reconcile these definitions.

As there are many theories about creativity itself, there seem to be many different creativity measures. The Torrance test of creative thinking [12] is one such example; it is similar to an IQ test and measures the creativity index of an individual. However, the Torrance measurement scheme does not capture the wide variety of areas and ways in which individuals can be creative.

An alternative is assessment through an inventory of self-reported creative activities and accomplishments [6]. This approach implies that individuals become more creative by participating in creative endeavors.

Another approach is the consensual assessment technique proposed by Amabile [1], which measures the creativity of a product, not an individual. According to her, "a product or response is creative to the extent that appropriate observers independently agree it is creative. Appropriate observers are those familiar with the domain in which the product was created or the response articulated".

In our undergraduate setting we used all three approaches.

Despite the range of definitions and measurement strategies, many agree that creativity is not an innate quality, and can be learned, practiced and developed through a variety of techniques.

III. THE MULTIDISCIPLINARY SETTING

The vehicle for our investigation was a multidisciplinary undergraduate seminar that we developed, in which student teams built non-human systems that conducted our college orchestra. Called "Conducting Robots", this semester-long course was offered four times from Fall 2009 through Spring 2011. Each time the course was cross-listed in the departments of Computer Science, Interactive Multimedia, Mechanical Engineering, and Music, and was taught by a team of four instructors, one from each department (the authors). We worked with an independent evaluator to develop and administer student surveys and interviews. In addition, students were asked to keep a reflection journal. These tools were used to assess creativity and document the creative process.

Throughout the course, students worked together in multidisciplinary teams, contributing and developing knowledge from within their own fields, as well as learning fundamentals from the other fields involved. At the end of each semester, each team was able to demonstrate a functional system that performed in a concert with student musicians. Systems were either animations or robots, depending on whether the team had mechanical engineers. Each system fit one of four categories: humanoid robots (like Honda's ASIMO whose conducting performance [7] inspired some of the students), humanoid animations, non-humanoid robots (including devices tailored for individual musicians), and non-humanoid animations (some of them akin to video game interfaces). Some of the prototypes are pictured in Figure 1.

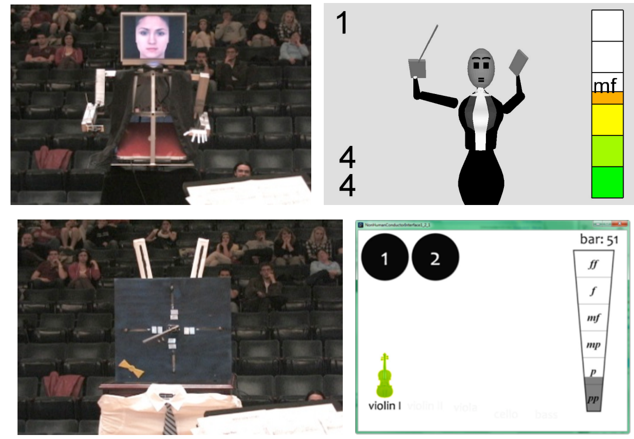

Figure 1. Conducting robot prototypes developed by students. Clockwise from top right: humanoid robot, humanoid animation, non-humanoid animation, and non-humanoid robot

The course presented a number of challenges for students and faculty alike, but all students built working conducting systems at a level that is rare in an undergraduate setting, and is more characteristic of graduate research. While doing so, they learned to collaborate with other students and apply their knowledge to other fields, as well as communicate cogently about their own disciplines to non-specialists.

A more detailed description of the course can be found in [10].

IV. CREATIVITY ANALYSIS

In an attempt to get a baseline for student creativity, we started each semester by administering the Abbreviated Torrance Test for Adults (ATTA) to the students. This test provides a creativity index, a standardized score that takes into account the raw test score for fluency, originality, elaboration, flexibility and adds extra points for ten different creativity indicators such as sound or movement, resistance to closure, synthesis of two or more figures, abstractness of title, etc.

We have found that, in spite of the small number of data points (over the four semesters we taught the class we administered the test to 60 students), the creativity index distribution was very close to the ATTA standardized score distribution. In other words our students scored very similarly to the national sample on which the test was standardized.

In general we found no significant difference between the creativity index of males and females, between classes, or between majors. The only significant difference was between music majors and engineering majors, with the music majors scoring higher. This result enforces the popular view of music being a more creative field than engineering.

We also asked the students to rate their own creativity on a scale from 1 (least creative) to 10 (most creative). This self-ranking was based on students' creative activities and accomplishments, following the approach in [6]. Interestingly, the only correlation that we found between the self-ranking and the ATTA creativity index was at the two ends of the spectrum, for the most and the least creative students.

As discussed above, the definition of creativity is still a matter of debate among researchers and laypeople alike. When we asked students to rate their own creativity, we also asked them to define it. A vast majority replied that creativity was “thinking outside the box”, and the ability to create something new. Only two or three students each semester mentioned using other peoples' ideas as part of the creative process. By the end of the semester, when students were asked to rate how the diversity of their team influenced the creativity of their solution, it was the exact opposite: only two or three students per semester did not give credit to other people's ideas.

At the end of the semester most students agreed that the multidisciplinary team environment increased the creativity of their project. They also reported that they were able to come up with creative solutions that they would not have found while working alone. This aspect was consistent, regardless of major. On a scale from 1 to 10 where 1 meant “not much at all” and 10 meant “an extraordinary amount”, the average rating of the multidisciplinary team’s impact was 7.3, 7.4, and 6.4 (in the three semesters when we recorded this data).

Here is how some students described the influence of the diverse environment:

“A lot of ideas were thrown around and it was nice to see how everyone tackled the same problem in different ways.”

“The knowledge, and also at times lack-there-of, of my group mates helped to force me to explore more creative solutions, musically. “

“If I had done this with just music majors our project would not have been as creative, I believe. We would have only come from one angle (plus we wouldn't have been able to build it!)”

“Whenever I drew a blank, someone else in my team was able to give an alternative approach to the problem. So many different minds collaborated within one group that it was easy to see outside the box.”

At the end of each semester we used the consensual assessment technique to rate the creativity of the student projects. The non-human conductors were ranked by three categories of observers: the student orchestra that performed while being conducted by the non-human prototype, becoming the users of these systems, the course instructors, and a multidisciplinary advisory board comprised of faculty members from each discipline who were not involved with the course.

While all evaluators found all solutions creative, the rankings varied from one evaluator to another based on their area of expertise: engineers appreciated the technical details, while musicians favored systems that conveyed all the information required from a conductor. What is more creative? A non-humanoid robot that is unlike anything we have seen before, or a humanoid robot that performs very close to a human? The first requires new definitions for all the information that is being conveyed to the musicians, an original solution that is not usually appreciated by the orchestra used to human gestures. The second may not seem very original to the outsider, but building a humanoid robot requires creative engineering.

Meanwhile, the course instructors ranked the creativity of the entire process, based on details unknown to outsiders. These included the creativity of solutions to various problems students encountered on the way, and the flexibility of students, some of whom made significant contributions in areas that were not related to their major.

Some of the musicians were tempted to give high rankings to the non-humanoid systems – after all, these were the most original – but most of them ended up favoring usefulness, and ranked the most useful systems (the ones that provided a good amount of correct and easy to understand information) as most creative.

When thinking of creative activities, drawing and writing are usually the first ones that come to mind. Our evaluators were challenged to look for different creativities. Whether it is drawing or building a non-human conductor, most of us agree that creativity involves original ways of looking at and solving problems. But in this day and age nobody can be a renaissance man anymore. People can be creative in some ways, and less creative in others.

The results of the ATTA test suggest that, at least in our case, engineering majors are less creative than music majors. But can their creativity be compared? Can we compare the Brooklyn Bridge to the Rhapsody in Blue, or Steve Jobs to Bob Dylan? Both the instructors and the advisory board agreed that most students contributed to the projects in a creative way, but their creativities were different.

Some of the creativities that we observed include:

1. Creativity of design – meeting objectives within constraints, adding additional features to the product that are not necessarily required (i.e., visually pleasing details, etc.).

2. Creativity of problem solving – innovative solutions to a variety of problems that need to be solved before the product can be fully built.

3. Creativity of knowledge acquisition – the various ways in which students looked for information that could help build their product

4. Creativity of self-definition – the flexibility in which students perceived their skill sets, regardless of their major.

How did individual creativity influence team performance? Students were asked to form teams without any specific input from the instructors. The only requirements were the number of teams, the number of students per team (which varied every semester based on the class makeup), and the fact that each major had to be represented on each team (with a couple of exceptions imposed by low numbers of students from a specific discipline who registered for the class in a particular semester). We encouraged students to “advertise themselves” by listing qualities that they thought would be useful for the project, and they self-selected. Invariably, at the end of the selection process there was one team made up of students who were not picked by other teams. Usually these were the students who were not proactive enough and did not advertise themselves as well as others.

Interestingly, the mean creativity index per team was either the same or higher than the class average, with the exception of the last team whose average creativity index was below the class average. Often this team ended up being ranked lowest by the observers participating in the consensual assessment.

Did students learn to be more creative? Looking at the types of creativity that we observed, the answer is yes. They were forced to meet objectives within a number of constraints, they learned how to communicate with people from other disciplines, and even solved problems using newly acquired knowledge from other disciplines. Perhaps most importantly, they inspired each other. And if we use the inventory of creative activities and accomplishments as a measure of creativity as in [6], and considering the fact that all student teams were successful in building a functional conducting prototype, then we can claim that student creativity increased through simple participation in the class.

V. CONCLUSION

Based on our experiences in the Conducting Robots seminar, we believe that a multidisciplinary environment and an attractive challenge can inspire and enhance the creativity of students. We have developed new methods for assessing the creativity of undergraduate group work and proposed a theory of Multiple Creativities to account for the various ways in which our students demonstrated flexibility and agility in their designs and prototypes.

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