Student Perception of Problem Solving Skills

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Abstract:

Problem solving is a critical component of a comprehensive 21st century education. This study investigates the perceptions of students of taking a university liberal education course designed to develop problem-solving skills. We describe how the participants in the study created their own understanding of what problem solving skills are and why they are important. Based on both quantitative and qualitative data collected before, during and after the course, students reported increased communication skills, increased awareness of the importance of problem-solving skills in their major, and significantly increased confidence in their problem-solving abilities. They also demonstrated a strong awareness of how the skills they acquired transfer to both academic and real-world environments.

Key Words:

Problem solving skills, student perception of skills, confidence, transfer.

Introduction

In his Partnership for 21st Century Learning Framework, Ken Kay (2010) invokes certain key skills today's students should develop: critical thinking and problem solving, creativity and innovation, and collaboration and communication. Problem solving skills such as analysis, transfer and metacognition also figure strongly in the revised Bloom's taxonomy (Krathwohl, 2002) and the facets of understanding outlined by Wiggins and McTighe (2005).

A question arises regarding how problem solving skills can best be developed in our students. As van Gelder (2005) points out, acquiring expertise in critical thinking is difficult. He notes that practice in such skills will enhance them, but also that transfer of such skills must be practiced. Many other authors have noted the need for sustained or "deliberate practice" (Ericsson, 2003, p. 31) to develop expertise in areas such as music, chess and sports. Metacognitive awareness is an important component of this deliberate practice, and hence a key factor in the development of problem solving and critical thinking skills. Metacognitive knowledge of multiple strategies, as well as knowing which strategies to use when, is obviously essential to good problem solving. But awareness of one's own strengths and weaknesses, and the ability to monitor and control one's thinking, are also crucial (Pintrich, 2002; Brown, 1987; Flavell, 1979, 1987). Zimmerman and Campillo (2003) additionally note that in concert with mere knowledge, other attributes such as personal resourcefulness and persistence, and motivational beliefs such as self-efficacy and learning goal orientations, are essential for proficient problem solving.

The *Problems and Puzzles* Course

At the post-secondary level, courses in problem solving are routinely offered in particular disciplines, such as business, engineering or computer science, but are generally narrowly focused on specific skills relevant only to that discipline. Our research grew out of the development and delivery of a broadly focused Liberal Education course based on solving puzzles, a course intended to develop more general problem solving skills in students from a wide variety of disciplines. The design of this course was motivated by a desire to offer students the opportunity to develop widely-relevant problem solving competencies in an engaged and active learning environment, based on puzzles. The course had three 50-minute classes a week, over a 13-week semester. Direct (lecture) instruction was minimized during class time, and instead students were given the opportunity to develop their skills and construct their understanding through practice tackling problems in an interactive and participatory context. A class would typically start with the distribution of one or more problems for students to work on, a brief discussion of relevant concepts and strategies, and significant time to work on these problems, concluding with a collaborative debriefing of the problem(s) at the end of the class.

The puzzles used in the course ranged from traditional math-equation puzzles, logic and counting puzzles, to weighing and measuring puzzles, to finding strategies for games, to word puzzles and other more open-ended and creative puzzles. An early example used in the course is Pòlya's (1945) water-measuring puzzle: "How do you bring up 6 liters of water from the river if you have only two (unmarked) containers of sizes 5 and 9 liters?" The problems and puzzles chosen were intentionally not mathematically technical, and were often solvable in a variety of different ways. In this context, students were encouraged to grapple with understanding the problem, to consider components of the problem they could solve if they could not immediately solve the whole problem, to work backwards from a possible solution, to analyze a process for solving the problem, to decide how to visually represent or mathematically encode their steps, and to make mistakes and learn from their mistakes. This was all carried out in a supportive, collaborative, collegial, and interactive classroom environment, where engaging deeply with a problem mattered more than solving it quickly. Students were free to work alone or in small groups as they chose, and to ask the instructor for help if they wished. The instructor and teaching assistant refrained from giving solutions or specific hints, but instead asked Socratic or reflective questions such as; “Are you making any progress?” or “Tell me what you are thinking so far.” In this way a community of learners was created, and the students often became teachers as they shared their ideas and new approaches with their peers and the instructor (Wismath, 2013).

Research Questions

The Problems and Puzzles course was piloted (with the first author as instructor and the second author as a co-instructor) in 2010, and offered a second time in 2012. We collected a variety of demographic and attitudinal data each time, in an attempt to track what problem solving skills we could teach students, and how such skills could be best learned and taught. Although the instructors believed that the first offering of the course was very successful, we had no objective information to support that belief. Our ethics approval did not allow for use of student grades; and, we suggest, while final course grades may be indicative of students’ abilities to respond to assignments and tests, they may not actually measure a profound or enduring acquisition of skills. In addition, the instructors had struggled during the development and first offering of the course with the issue of what skills exactly could be taught, and how they could best be learned. As the classes in the first offering increasingly became dialogues between the instructors and the students, we also entered into a dialogue with students about the skills and attributes they were learning or wanted to learn. The goal of our 2012 research therefore was to investigate, in the absence of direct measures of generic problem solving skills, what students themselves perceived as valuable in their learning. We were particularly interested in tracking the students’ perception of problem solving skills, and, from a “constructivist” perspective (Olson, 2007, p. 75), how students created their own understanding of what problem solving is and why it is important. A number of questions framed our approach, influenced by the literature on cognitive problem solving (Olson, 2007; Sternberg, 1984, 1986b; Zimmerman and Campillo, 2003), metacognition (Flavell, 1979, 1987; and transfer of skills (van Gelder, 2005):

- What skills, if any, did students perceive they had learned?
- Could students identify specific skills that they perceived contributed to their acquisition of problem solving abilities?
- Did they perceive confidence as an important component of problem solving ability?
- Did their confidence in their abilities change as a result of their participation in this course?
- Did they regard the skills they learned by working to solve puzzles as transferable, either to other areas of their academic lives or to the world beyond their university courses?

Methodology

The research described here reflects an early component of an on-going mixed-methods research project. Research ethics approval was obtained from our institution for this on-going study (Protocol # 2011-084), and efforts were made to ensure appropriate confidentiality and anonymity of participants. Students were informed at the start of the course of the on-going research and given the choice to participate, were able to opt out at any time, and were assured that the instructor of the course would not know who was participating. Data were collected, coded and analyzed by a research assistant, after the course had ended and all grades were submitted.

In Spring 2012, 60 students were enrolled in the Problems and Puzzles course, 38 consenting to participate in our study and provided complete data. A mixed-methods approach was adopted, which entailed collecting a variety of quantitative and qualitative data from participants. Basic demographic information collected included age group, gender, year of study, discipline major, and reason(s) for enrolling in the course.

In this preliminary iteration of our research, the Barsch Learning Style Inventory (Barsch, 1991), which generates values for "visual, auditory, and tactile" learning styles, was administered at the start of the course, both as a source of demographic data, and as a learning asset for students in discussions about metacognitive practices. In subsequent years the "VARK" learning styles inventory (Fleming, 1995) has replaced this instrument. As well, the Gregorc Thinking Style Inventory (Gregorc, 1979) was administered at the start of course. This instrument, which provides respondents with scores on two intersecting continua of thinking styles (abstract-concrete and random-sequential) was similarly used both as a source of demographic data and as a learning asset for students.

While there is certainly a plethora of different and more recently developed such instruments available, we have continued to use the Gregorc inventory, as its descriptors provide a simple and understandable measure for students regarding their own thinking styles, and additionally parallel the substance of Polya's (1945) problem solving paradigms which are fundamental to the course. An attitudes and attributes survey was designed by the research team, piloted in 2010 and revised in 2012. It consisted of 37 five-point Likert-type questions, and was administered at both the beginning and end of the course to provide pre- and post-test measures of reported student perceptions of attitudes about puzzles and problem solving in general, as well as reported perceptions of specific skills, abilities, and attributes (Appendix A). This instrument provided quantitative measures of relevant student-reported self-perceptions and was intended to measure the success of the course, as perceived by the student participants.

Qualitative data was collected primarily from student responses to three written-response "reflection" assignments, submitted at intervals in the course (the first submitted near the beginning of the course, the second at approximately mid-term, and the third handed in at the end of the course). These "reflection" assignments were intended to elicit students' perceptions regarding problem solving skills in general and their own development of these skills in particular, and although part of the course, they were graded for completion only. Additional qualitative data was derived from the transcript of a one-hour focus group session held at the end of the course, which solicited anonymous comments from a volunteer sample of the research project participants. Ten students participated in this focus group, which was conducted separately from any course requirements and after final grades had been assigned.

Findings

In this section we describe the findings from our data collection. After some demographic information, we present student views on four main areas issues related to our research questions: confidence and self-efficacy, metacognition and self-awareness, transfer to academic work, and transfer beyond the academy. Quotations from the focus group participants are identified as such; all other quotations are taken from student reflection assignments.

Demographics

The students in this study formed a diverse group, in terms of majors, gender, reasons for taking the course, and thinking (Gregorc, 1979) and learning (Barsch, 1991) styles. Most (94.7%) of the 38 students voluntarily participating in the study identified as 19-24 years of age. Based on number of university courses completed prior to taking this course, 34.2% were third-year students, 39.5% were in fourth year, and 15.3% in first or second year. Majors declared by the students included Fine Arts, Mathematics, Sciences, Humanities, Social Sciences, and Kinesiology. Of the 38 participants, 22 (57.9%) were female and 16 (42.1%) were male. A majority of respondents (63.2%) indicated they had registered in the course in order to either fulfill a science elective requirement or to add an extra science course credit to their program. Interestingly, 57.9% of respondents identified themselves, based on the Barsch Learning Styles Inventory (1991), as predominantly visual learners, with another 23.7% self-identifying as predominantly auditory learners. In terms of Gregorc's (1979) Inventory of Thinking Styles, respondents self-identified relatively evenly across the categories (concrete-sequential, abstract-sequential, concrete-random, and abstract-random).

Confidence and Self-Efficacy

A compelling outcome of this study involved students' perceptions of their own skill and confidence as problem solvers. As Zimmerman and Campillo (2003) note, "having knowledge and skill does not produce high-quality problem solving if people lack the self-assurance to use these personal resources" (pp. 241-22), and confidence and self-efficacy are predictive of persistence and effort in problem solving.

In response to five-point Likert-scale survey items (where 1= "Strongly Disagree" and 5= "Strongly Agree"), two items asking students to assess their abilities and confidence showed a significant difference from pre- to post-test, based on a paired sample t-test analysis. The mean response to "I have good problem solving skills" rose from 3.45 to 4.13 at a significance level of $p < 0.001$, with an effect size (Cohen's d) of 1.007 (Table 1).

Table 1 Pre- and post-test response to "I have good problem solving skills."

pre-test		post-test		paired sample t-test			effect size	
mean	stdev	mean	stdev	df	t value	p value	Cohen's d	r
3.45	0.760	4.13	0.578	37	6.372	p<0.001	1.007	0.450

Similar changes were evident in responses to the item “I am confident in my ability to solve problems” (Table 2). The mean response rose from 3.47 to 4.11, again at a p-value of less than 0.001.

pre-test		**post-test**		**paired sample t-test**			**effect size**	
mean	stdev	mean	stdev	df	t value	p value	Cohen’s d	r
3.47	0.830	4.11	0.649	37	4.751	p<0.001	0.859	0.395

Table 2 Pre- and post-test response to “I am confident about my ability to solve problems.”

Further analysis of responses to these two questions yielded a significant gender component: female students rated themselves much lower on both abilities and confidence than males at the start of the course, but also showed a significantly higher increase from pre- to post-test scores compared to male students, as also reported by Wismath and Zhong (2014).

Another survey question which showed a significant (p = 0.001) change from pre- to post-test administration was “I like doing math word problems” (Table 3). Since math skills are a source of great anxiety to many people, and word problems in particular are found to be difficult (American Association of University Women, 2008; Schiebinger, 2001), this shift, we suggest, indicates increased student confidence in problem solving skills, and concomitant “enjoyment” of problems and puzzles.

pre-test		post-test		paired sample t-test			effect size	
mean	stdev	mean	stdev	df	t value	p value	Cohen’s d	r
3.05	1.102	3.78	1.004	37	3.648	p=0.001	0.693	0.327

Table 3 Pre- and post-test response to “I like doing math word problems.”

On the third reflection assignment at the end of the course, students were asked “Do you think that you are a better problem solver after taking this course?” Of the 38 respondents, 32 (84.2%) indicated that they did indeed think so, using phrases like “definitely”, “most definitely”, “absolutely”, “much better now”, and “I am certain that my ability […] has increased.” One student wrote that “I got more strategic, more efficient and more successful”, while another described a definite improvement in math-related skills. Students’ perceived skill acquisition included knowing a variety of strategies and techniques, knowing which strategies to use when and why, knowing what to do if they were stuck on a problem, as well as understanding the importance of exploring a problem fully and carefully before plunging in, and being able to change one’s point of view when necessary.

Three of the 38 students (7.9%) described minimal progress since they were already very confident to start with. Another three students (7.9%) were less certain of any improvement. One student described herself as unsure if she had improved, but feeling “more coherent”, in the sense of arriving at answers in a more logical manner. One student “wouldn’t say that I am better problem solver, but that I am now a problem solver with a larger variety of tools at my disposal.” Another respondent reported that:

> I haven't proven to myself that I can use the skills properly yet, as I still haven't gone into the real world to use these new skills in a practical way […] I think I will be better able to apply these skills in a way that suits my life.

As noted by Zimmerman and Campillo (2003), confidence and self-efficacy are important facets of success in problem solving. Although we did not ask specifically about confidence in this reflection assignment, seven students spontaneously used the word "confidence" themselves, and several more expressed comparable feelings, and often with respect to mathematical problems:

> Before taking this course, I would simply give up or avoid entirely any problem that hinted [at] any form of mathematically-related thinking or logical reasoning. This course has taught me that I'm capable of solving these types of problems as well as helpful ways to approach problems that intimidate me.

> I feel more confident in my problem solving skills, especially in the area of logical reasoning. I also feel more confident in my problem solving skills in math.

> I'm an English student…numbers terrify me, and so this class has really helped build my confidence…and it also built up my confidence in math as well. (Focus group)

Other student comments additionally reflect increased confidence in their own general problem solving abilities:

> When I come across a problem or a puzzle, I usually feel very anxious because I never know where to start. After taking this course, I can finally take a step back and find more than one approach to take. It gives me patience and confidence to try and tackle a problem without the fear of getting it wrong. I now know that I can use a mistake as a learning experience.

Two other students reported: "Most of all I've realized I always had the ability or capability to be a good problem solver." and "Trying this course that was completely outside my comfort zone only developed characteristics that established the self-belief that I have the ability to achieve anything I put my mind to." Another said "Most importantly, I tried something new and I was able to comfortably adjust to it, which is something that I find I often struggle with."

The ethics approval for this study did not include the use of student grades, and we thus did not utilize an "objective" measure of student academic progress. As noted earlier, it is debatable whether or not a student's course grade would in fact reflect the kind of attributes we are interested in (such as acquisition of generic problem solving skills, changes in attitude and confidence, and transferability of skills and knowledge to other areas). In the absence of grade measures, we were more interested in knowing if students themselves felt they were learning to be better problem solvers. Our data, we suggest, indicates that a majority of the participants perceived themselves to have developed or improved their problem solving abilities. This does not necessarily indicate actual progress in skills development, but research by Zimmerman and Campillo (2003) indicated that confidence is an essential prerequisite to skill development and use.

Metacognition and Self-Awareness

Metacognition is often loosely defined as “thinking about thinking” (Flavell 1979, 1987), and involves two main aspects: knowledge and regulation. Metacognitive knowledge includes knowledge about one’s personal thinking style and strengths and weaknesses, as well as knowledge about various strategies to use in problem solving and process knowledge such as which strategies to use when and why. Metacognitive regulation involves the monitoring and planning of one’s thinking and problem solving, being aware of whether strategies are working or if progress is being made (Brown, 1987). The *Problems and Puzzles* course emphasized metacognition both as a topic and as a tool in problem solving, and students were encouraged to think about the processes of their own thinking (Wismath, Orr, & Good, 2013). Although we did not specifically query students about this aspect of the course either on the reflection assignments or in the focus group, their comments did reveal an understanding of the importance and benefits of metacognitive growth. Comments such as “I never realized how much brain power it really takes to tackle a problem” and “It [practicing problem solving] helps your brain figure out how to figure something out” illustrate this. Another student remarked that “I have learned a lot about the way I think and how I work through problems.”

With respect to metacognitive knowledge, a majority of students described knowing a much wider array of strategies for solving problems, and increased awareness of how to choose a strategy – a critical aspect of metacognition particularly regarding problem solving (Pintrich, 2002). They were also able to identify a number of metacognitive strategies they viewed as important, from learning to go more slowly, in the sense of thinking and planning more before plunging into details and calculations, to the importance of keeping an open mind, trying to think of other options, and changing one’s point of view if necessary. Several students also remarked on the value of making and learning from mistakes; for instance, a student in the focus group reported that “I also thought the course taught you to learn from your mistakes, like if that didn’t work, don’t stop there, find out why or use that to help try again.” Respondents additionally described perceived benefits from an increased awareness of their thinking and learning styles:

> I think that I will continue to self-analyze my thought processes and ways of thinking and I believe it will have a positive effect on the way I approach different situations in the future.
>
> This class has also helped me by teaching me about my learning style. […] Since I know my learning style I am better able to adapt problems and situations to a way that I will be able to understand and solve them. […]
>
> […] the awareness of my learning style that I have gained in this class has really allowed me to understand why I have been successful at many things … and why I have been unsuccessful in other areas.

The development of good metacognitive skills has been linked to success in critical thinking and problem solving (van Gelder, 2005; Pintrich, 2002; Scruggs et.al., 1985), to intelligence in general (Sternberg, 1984, 1986a, 1986b) and to enhanced academic performance (Borkowski, Carr & Pressley, 1987; Garner, 1990; Carr, Kurtz, Schneider, Turner & Borkowski, 1989). Thus metacognitive skills are an important contributor not only to problem solving skills but to general academic skills. Our data shows that students saw themselves as making metacognitive progress, which they could then use in other areas as well, as discussed in the next subsection.

Transfer to Academic Work

In laboratory investigations of problem solving skills, small self-contained problems or puzzles are often used. But as Ericsson (2003) points out, "The crucial assumption that basic mental functions studied with traditional laboratory tasks are the same as those that underlie and constrain performance in everyday life has not been directly tested empirically in psychology" (p. 45). Moreover, Davidson and Sternberg (2003) comment that solving such artificial puzzles "probably does not require the same motivation, social interaction, preparation time, restructuring, and solution procedures that individuals need to solve significant, real-world problems" (p. 165). A key question within our study therefore was whether participants perceived that the skills developed by practicing solving puzzles are skills that transfer to other areas of academic work and beyond. We thus asked the students if they thought they had gained skills that would be transferable, both to their academic work and to "real life". Both the final reflection assignment and the anonymous focus group asked students to discuss the following question: "Are any of the critical thinking or problem solving skills developed in this course transferable to other areas of your academic life?"

Six students (15.8%) indicated that they found little transferable from the course to their other academic work, while 32 students (84.2%) did find some transferability. Of those reporting no transfer, three were Fine Arts students (one in art, two in music) who felt that problem solving was not relevant to their studies, and another felt that the benefits to him were more social than academic. A fifth student noted that he was in his final semester of university and hence saw little benefit, but thought that more junior students would see some transfer of skills. Another student found little direct transfer, but did note being able to better manage time and workload.

Nevertheless, 32 participants (84.2%) stated that they perceived some degree of transfer, and listed one or more skills or strategies they used in other areas of study. Three students majoring in mathematics or computer science found direct application to problems and assignments in their majors, and a pre-law student perceived the skills developed to be "100% transferable". Three science students mentioned their lab research, identifying skills such as hypothesis development and testing and use of logical reasoning. Three students noted that academic study seems to consist of a series of problems, in the form of homework, quizzes and exams, and hence all problem solving skills are continually useful in their student life. Three students mentioned skills they found applicable to their planned teaching careers or their current teaching practicum assignments.

Eight students identified enhancement of their logical thinking and deductive reasoning skills as an important benefit. This included aspects such as lab research, developing arguments in essays, and reasoning through multiple choice and written test questions. Five students listed metacognition as significant, in helping them with writing papers, taking notes and studying, and in preparing them for careers as teachers. Five students described enhanced time-management skills, with better ability to organize and prioritize their workloads. Five students also described learning to carefully understand a problem before plunging in as an important transferable skill, taking one's time to understand subtleties and to pick out relevant versus irrelevant information. Other general strategies mentioned included knowing different ways to solve a problem (three students), reducing a large or complex problem to smaller pieces (three students), and being open-minded and willing to change one's point of view as necessary (also three students). This reflection comment indicated awareness of acquisition of critical thinking skills: "I also noticed that I rely heavily on deductive reasoning in all aspects of my life. I think that being aware of my own thought processes has really helped me in writing papers, taking notes, and studying."

Several students who were English majors commented on the benefits for writing essays and analyzing texts: "being able to explain efficiently how to solve a problem is very similar to how a strong essay proves its thesis" and "the critical thinking skills are also applicable to the processes that go into the analysis of a work and the logical development of an argument." A science major also linked problem solving skills to lab research, and the creation and analysis of experiments. One participant in the focus group reported that she "had the easiest time getting through this semester and studying and everything in all of my other courses and I think that it really came from what I was doing in here.

A number of participants identified communication skills as something they had improved through this course and then used in other areas. Students in the course frequently communicated both their ideas and their solutions to each other in class, and also were required to write careful solutions to selected problems on weekly homework assignments. Students generally found it difficult at first to produce written explanations, often losing marks for incomplete or poorly explained logic. But this gradually improved over the semester; and, as one student remarked in the focus group after the course, "of course I'm going to explain myself – because that is how you do a puzzle now … you have to explain it to get the answer." Another reported "I knew what I was doing, but putting it on paper was a struggle. As the class went on, my explanations grew clearer and better." A similar focus group comment indicated that "when you explain it, it helps you learn it so much more." Other responses echoed important growth in these skills:

> At first I did not like having to write out the step by step process. This however has helped me to articulate problems that I encounter in other circumstances. One of my main problems was articulation within an essay and now I find that I am able to state my argument and support it with relevant facts.
>
> By being required to do write-ups for the weekly assignments, I have learned how to better explain my ideas in a logical, sequential way that is very different from my own thinking style. I have learned that I need to explain the process step-by-step, in a very logical order for most people to understand.

A number of students also reported improved oral communication, derived from discussing puzzles with their classmates and family and friends, and further identified benefits from working with people of different thinking and learning styles.

> My communication skills have also improved. I am better able to communicate with peers when solving problems.

> Because of this course, you learn to see a problem through someone else's eyes. … This is an extremely important social skill, being able to understand others, that goes far beyond just problems and puzzles.

Although it was not explored in our reflection questions, our pre- and post-survey also looked at whether students perceived problem solving skills as important in their own discipline or major. There was a significant (p = 0.001) increase as measured by a paired sample t-test, on responses to "Problem solving skills are an important part of my major." We suggest that this may also be an indicator of academic transfer, in the sense that students became more aware of some of the more general skills needed in their majors, beyond simple memorization of facts (Table 4).

pre-test		**post-test**		**paired sample t-test**			**effect size**	
mean	stdev	mean	stdev	df	t value	p value	Cohen's d	r
3.58	1.056	4.03	0.885	37	3.468	p=0.001	0.462	0.225

Table 4 Pre- and Post-test response to "Problem solving skills are an important part of my major."

In his 2005 article "Teaching Critical Thinking: Some Lessons from Cognitive Science", van Gelder points out that critical thinking in general is hard and must be extensively practiced, but also that transfer of such skills must be explicitly discussed and practiced. Pedagogically, asking our students about what transferability of skills they experience is a way for them to articulate and be aware of transfer, and in effect to practice it. The data presented here, while mainly qualitative, supports our argument that significant transfer of skill is occurring, and that learning about and practicing problem solving contributes to the growth of very general critical thinking skills useful in a variety of academic areas.

Transfer Beyond the Academy

We also asked participants about skills which they perceived would transfer from the course to their lives outside of academia. They identified three key areas: the process of problem solving, attitudinal attributes, and some meta-level skills. Fundamentally, students perceived that learning the process of problem solving was more important than simply solving problems. As one student commented, "we learned to think differently in order to solve these problems, and it is the thinking process that is transferable to real-life situations." Participants remarked on having learned to understand a problem carefully, to determine key information, to break a complex problem into parts, and to brainstorm and work together:

> [T]he general concepts of problem solving can be applied to anything; how to start a problem, what to do when you hit a bump, and how to follow through to the end. Although we were simply solving puzzles and games, we were really doing smaller versions of real-life scenarios.

> I find that the purpose of some of those fun games and problems are to get you thinking and to help you build skills that will help you in the real world. Thinking through the problem carefully and going back to double check your work are important ones that translate well from fun and games to real world problems.

> Obviously, the real world almost never functions like a puzzle does. However, if we can learn anything from how we solve problems and puzzles in class, it's that patterns reoccur in nature with startling ubiquity if one is patient enough to look closely at all the information. If one is careful enough with real world problems, looking for patterns and understanding the issues is really just a way of solving the same kind of problems as the ones in class, but on a much larger scale.

A second key aspect participants remarked on was their development of patience, determination and persistence; for example: "[T]he thing I found most rewarding and that I'll use forever is persistence" and "I do believe that learning how to problem solve will help you develop attributes like perseverance, determination, thinking outside the box, and confidence." And:

> We have all gotten frustrated at some point when we have not been able to figure out a problem but with time and determination we can get it. This is the same in the real world where not everything will be an easy problem to solve but if we try different strategies and follow through we will find a solution to the problem at hand.

> Perhaps most importantly, many respondents referred to their acquisition of meta-level skills such as critical thinking and logical reasoning, and shared various examples of how they use such skills beyond the university, in contexts ranging from politics and policy development to getting a job and running a business:

> Throughout the course I have become much more competent at addressing sub-sets of larger problems and more clearly identifying larger problems. This has helped with writing assignments, and debates (both formal and informal).

> Knowing how to think logically and critically … is something that I feel everyone should integrate into their lives. This could be applied not only in academics, but in the personal and social aspects of life as well. I believe that by knowing how to think properly, you can do essentially anything.

> Skills developed in this class are very relevant to the "real world," in a work environment it may be the key to getting the job or not. It also … makes you more valuable an employee.

In terms of the substance and impact of transferability, students identified the transformative nature of their acquisition of problem solving skills in this collaborative active learning environment. The following conversation occurred during the focus group done after the end of the course:

> I think this class should be mandatory for first year students; imagine how valuable this would have been in your first year of university.

> I think if I would have taken this [course] in my first year, it would have been significantly more life changing.
>
> I wish I would have taken this course in my first or second year because it has provided me with quite a bit of knowledge (especially in terms of problem solving) that would have been very useful in the past.

Although claims of transferability beyond the academy are speculative and anecdotal, we argue that our students saw benefits of the skills they were developing, skills they used now and anticipated using in the future, in a variety of ways.

Limitations, Discussion and Conclusions

Our study has a number of limitations. Two of the surveys we used, the Barsch and Gregorc, did not reveal much useful information relating to the questions we wished to address. As noted above, in subsequent studies we have used the VARK questionnaire (Fleming, 1995; Fleming and Mills, 1987) instead of the Barsch survey, as being more current and more indicative of the spectrum of learning styles relevant to post-secondary education. A further limitation has been the lack of a direct measure of the kinds of problem solving skills and attributes in which we are interested. It would be useful in future research to administer a standardized pre- and post-tests of such skills; but by the very nature of problem solving, it would be necessary to create reliable and valid different but equivalent tests for pre- and post-use. As noted, we did not utilize student grades, and even if we had, suggest that there would again be no useful equivalent pre-course comparison to use. A more intensive long-term study might attempt to track students' cumulative grade point averages over time, or provide a follow-up focus group one or two years later, to see if taking this course had lasting effects on students' academic achievement.

Kay (2010) describes the key skills required of today's students as critical thinking and problem solving, creativity and innovation, and collaboration and communication. Cookson (2009) suggests that the vital attributes of "the 21st century mind…[are] critical reflection;…empirical reasoning,… collective intelligence,…and metacognition" (pp. 10-12). Acquisition of such skills, while difficult to assess directly beyond the confines of a closely controlled experimental setting or within a narrowly focused discipline-specific course, nevertheless defines the fundamental characteristics of problem solving competency applicable in a much broader (real-world) context. One might indeed see the purpose of a university education as the development of such skills in all students.

Our course has been an attempt to provide a learning environment for students to develop problem-solving and critical-thinking skills, in a context outside of any particular discipline. As instructors in a liberal-education focused university, we see the development of these skills across and beyond disciplinary boundaries as fundamental to education, and have grappled with how best we can teach and our students can learn such skills. We argue that participants in our study have acquired these kinds of attributes and skills, through active engagement with and reflection on the practice of learning to solve a variety of puzzles and problems. Student responses to both survey questions and self-refection assignments indicate their perceptions of maturation in problem solving ability. These students further indicated the transferability of these learned abilities beyond the confines of the course in which they were engaged. In terms of personal and intellectual development, students indicated a significant increase in both "confidence" and "skill" in problem solving. Moreover, respondents identified their growth in metacognitive knowledge and application as salient factors in their perceived improved ability and confidence.

The question remains whether or not this self-reported acquisition of problem solving competencies is actual or illusory. We contend that students have in fact gained substantive abilities, based on the reported transferability of these learned attributes and skills not only to other courses at university but to the world beyond the walls of the academy.

How can problem solving skills, in the broadest sense, be developed? This was the challenge we faced in designing and implementing a course of this nature. We suggest that students in our course believe that such skills, and the associated attributes, can indeed be learned and developed. The "teaching" of such skills however, we posit, cannot be best accomplished in a traditional lecture-format class, but rather requires a carefully structured active learning environment which facilitates the introduction, practice, and eventual deep understanding of problem solving as a process. This facilitated engagement, we believe, allows students to construct their own learning, and their own understanding of the benefits of that learning.

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Appendix A

Attitudes and Attributes Survey

Level of agreement with each statement …

(Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree)

1. I like doing routine math calculations
2. I like doing writing assignments
3. I like doing math word problems
4. I enjoy games and puzzles
5. I am creative
6. I am a linear thinker
7. I am a logical thinker
8. I am intuitive
9. I like to find the one right answer to a question
10. I like problems with real-world applications
11. I like to think about abstract ideas
12. I am a playful person
13. I like to do meaningful work
14. I like to focus on details
15. I like to see the big picture when I tackle a problem
16. I like to break a task into smaller parts to work on
17. I am persistent
18. I am open to new ideas
19. I am patient
20. I am determined
21. I am flexible
22. I like new challenges
23. I like to see a project through to completion
24. I like to work with others
25. I like to work alone
26. I am good at explaining my ideas to others
27. I like to "brainstorm" ideas

28. I like to “talk through” ideas
29. I like to reflect on my own thinking
30. I get frustrated when I can’t solve a problem
31. When I start a puzzle I quickly get “hooked” on it
32. I have good problem-solving skills
33. I am confident about my ability to solve problems
34. I am nervous when I have to tackle a new problem
35. Problem solving skills are important in my major area of study
36. Problem-solving skill will be important in my intended career
37. I use problem-solving skills in my social relationships