Identifying and Recommending Teachable Techniques from Academia and Industry to Prepare Learners to Solve Complex Problems

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Abstract

This paper presents observations and information that can prepare learners to solve complex problems. Complex problems can range from difficult, technical research problems to market strategy development where many variables are ill-defined. The content forming the research hypothesis and models that are leading to education focused recommendations are based on both classroom and industrial experience. The concept is that the classroom environment does not typically lend itself easily to the instruction of techniques that are used to solve complex problems in industry or even more challenging; investigations in the academic research environment. This paper will focus on the comparison of the classroom to industry, so as to illuminate the education opportunities for the majority of engineering students who will enter non-academic research and industry careers. The first model contrasts with numerous examples of ways complex problems are solved in a classroom and the industrial setting. In a classroom setting, due to time constraints and the need to teach theoretical concepts, problems selected need to be finite and resolvable by students within the extent of the topic that is studied. In industry the complex problem exists, and the correct theory to be applied and the techniques that need to be engaged must be correctly found. Due to this shortage of experience in handling complex problems, students who are entering the industrial setting from the classroom setting often have not been exposed to techniques identifying complex problem solutions. The second model contrasts documented techniques used in industry today to solve complex problems. These include, but not exclusively individual characteristics, individual thinking, literature and media, corporate systems and the academically researched strategy development techniques. Finally, results of a survey used to assess which category of techniques would be most preferred to teach in the classroom environment will be shared. A summary of the category techniques and survey results will serve as the basis for a recommendation of information that can be shared in a classroom setting that can leave learners prepared to solve complex problems.

Introduction

In the competitive market, companies are always looking for a new way to improve their products to create a profit. The “new way” is a complex problem that can lead to further complex problems on the path to a solution. They are ill-defined and have barely any components to work with. Industries hire engineers to solve these complex problems, but when they arrive they use books or enroll in classes to teach themselves techniques. This lack of
knowledge appears to be signaling that something was missing from their education. If we look into the classroom setting, students are constantly answering close ended well-defined problems. This lack of complex problems lead to issues when they make the transition to the industrial setting, where it is a necessity to know techniques. This paper approaches through research, interviews and surveys how this problem can be solved. Through research, the contrasts between classroom and industrial setting shed light on the lack of complex problems in the curriculum. Research and interviews combined formed five techniques that could be used to teach how to solve complex problems in the classroom. Finally the survey results are then used to single out the techniques that are most preferred by professionals in the academic field. With those techniques, a curriculum can be formed in order to implement how to solve complex problems.

**Background**

Solving complex problems has been a necessity in order for companies to keep their hold in the market place. These problems are ill-defined and often have no direction to them and can range from avoiding bankruptcy to innovating new products. In order to solve these problems, many different techniques have been developed by engineers and are used to solve current issues faced in the industrial setting.

In the classroom setting, students are given close ended well-defined problems where they must solve accurately for proof of understanding. In preparation for their careers, through secondary and postsecondary education, they must pass multiple tests that include a great multitude of close ended well-defined problems found in the form of multiple choice and short answer.

There are many differences between the industrial setting and the classroom setting, but it is only in industry where ill-defined complex problems cause the most amount of trouble. There is a lack of such problems in the classroom setting. This creates an issue when newly hired engineers are challenged to solve complex problems they have very little experience in. In order to address the issue, possible techniques must be applied in the classroom in order to prepare students for the industrial setting.

Much research has been conducted about the techniques used in the industrial setting and has been presented to industries in order to teach engineers quickly how to solve complex problems. If this research can be put to use earlier in line such as the classroom environment, this can prepare students to better transition from the classroom to the industrial setting. For this paper, in order to develop the central idea and create the connections between the classroom and industrial settings and to further define the techniques used to solve problems some key insightful books and papers were reviewed. *The Opposable Mind* has combined multiple interviews of great leaders and thinkers to analyze what made them great. One of the interviews were with Michael Lee-Chen who was the CEO of AIC limited. In 1999 he was facing a change in what stock buyers wanted and the failing of his money management firm. However he refused typical solutions as an option and instead sold some capital items and then invested all the earnings on
one financial stock. This raised the stock value from $15 to $30 per share and saved the company.\textsuperscript{11} This type of thinking was described as integrative thinking and was used to solve a complex problem. \textit{Cognitive misfit of problem-solving style at work: A facet of person-organization fit} and \textit{Creativity and the finding and solving of real-world problems} gave further insight in current use of problem-solving in the industrial setting.\textsuperscript{6, 14} \textit{Recent developments in applied creativity} approaches techniques that can be used to solve complex problems.\textsuperscript{8} \textit{Cognition, creativity and entrepreneurship} and \textit{Problem construction and creativity: The role of ability, cue consistency, and active processing} both combine techniques and to address complex problems in the industrial settings.\textsuperscript{16, 21} Eventually many techniques were researched and defined, but it became apparent that they could be classified into five technique categories. This approach was also supported by interviews in Fortune 500 companies. The five techniques determined are; individual characteristics, individual instinct, individual thinking, academically researched and systems. In order to procure better definitions for the techniques that can be used in the classroom, further research was needed, along with the preferences of professionals in the academic field.

**Purpose**

The purpose of this paper is to present observations and information that can prepare learners to solve complex problems. The comparison of the classroom to industry illuminates the education opportunity for the majority of engineering students that will enter non-academic research. A two model approach is used to achieve the purpose. The first model will contrast the classroom and the industrial setting, and the second will contrast different documented techniques used in industry today to solve complex problems. The difference between well defined closed ended problems and complex problems is also critical. Closed ended problems have every component needed to solve the problem while complex problems can be missing multiple components. In comparing the classroom to industrial setting in model one, differences emerge when assessing a well defined closed ended problem to a complex problem. The classroom setting often uses well defined closed ended problems to teach concepts, while the industrial setting is teeming with ill-defined complex problems as that is where business competition occurs. Model two contrasts the different documented techniques used in industry today such as; academically researched, systems, individual instinct, individual characteristics and individual thinking. The category academically researched builds upon existing and new research strategies. Systems is a category that focuses on the process in which a solution can be achieved. The category individual instinct is a personal strategy that often comes from experience or a gut feeling. The category individual characteristic is about the personal traits that can be applied to solve complex problems. Individual thinking is a category that
focuses on the beginning steps of solving complex problems. Each technique is evaluated on how they can be taught in the classroom and how they can be applied by students. A survey was then developed as an instrument to identify what educators believed should be prioritized. The survey was conducted across the nation at different academic institutions. The respondents include professionals in the field engineering education. The number of academic institutions in which the survey was conducted totaled over 80. Preliminary interviews were conducted in a well known annual education conference and at Fortune 500 companies. Later surveys were developed and conducted after one to one conversations with professionals in the field of engineering education.

Discussion

Model one: Inputs on the Definition of the Problem; Classroom vs Industry

Model one of this research involves qualitative discussion in both classroom and industry to find the differences and similarities between the two settings. Starting in highschool, a type of curriculum is introduced called the Advanced Placement courses, known as AP courses. They are developed by the College Board and “consist of a full high school academic year of work and are comparable to ... courses in colleges and universities.” These courses range from college level art history to college level calculus. At the end of the year, AP Exams are taken by students to assess their comprehension in concepts and techniques of the topics covered. The exam is a two part examination that contains multiple choice and a short answer section where all the components are available; a close ended well-defined problem. This use of close ended well-defined problems in multiple choice and short answer response is also found in major tests as well in the PSAT, SAT and ACT. These test are all taken by high school students who are planning on attending college, due to many colleges requiring a certain score from these tests. The SAT and ACT have a multiple choice section and a short answer response where all the components are given and the PSAT is entirely multiple choice. In order to prepare students for these large multiple choice sections, majority of the curriculum in high school classes use the same style of close ended well-defined problem questioning in the courses.

Many university courses also apply multiple choice and short answer questions that are close ended well-defined problems in order to assess student comprehension. The Learning Commons is a represented by many universities to provide their students tips. In this reference it is noted that “multiple choice exams are common in courses which cover a lot of factual information.” Questions with the goal of covering factual information means that their is only one answer, making it a close-ended well-defined problem.

When having a qualitative discussion in the industrial setting of Fortune 500 industry, the first thing one notices is the amount of books, journals and other resources spread out around the
office. Many cubicles have books connecting to different strategies, processes and personal development. The books are not just located in cubicles, but also in meeting rooms, recreational rooms and labs. The presence of these kinds of books made it clear, many engineers at this did not come in knowing strategies, processes or how to develop their skills in an industrial setting and had to learn problem solving through other routes than what was instructed in college. When asked in an interview how they solve complex problems, many replied they work in a team and generate ideas. Then for the idea to be put in effect, the team split into specialized groups such as product design or finances and kept connection through a general manager. If the final product was not enough to solve the problem, they would generate another idea until the problem was solved. Designing and formatting a new product is the complex problem because not all the components of solving the problems is there nor is there one correct solution. Finding the solution is what industries are always trying to do because this unknown area is where companies compete. The first company to solve the problem is the first to reap profit.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Well-defined Problems</th>
<th>Complex Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom</td>
<td>Commonly used to teach curriculum in the time constraints.</td>
<td>They are rare to find due to the time constraints of a class period. The lack of ill-defined problems in the classroom is the problem.</td>
</tr>
<tr>
<td>Industrial</td>
<td>Used in menial office tasks.</td>
<td>Most problems faced in the business are complex problems. This is where company competes.</td>
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</tbody>
</table>

Clearly, the endpoint being tested in the academic environment is not the problem type confronting the engineers in industry. Addressing this difference requires understanding the technique to solve complex problems.

*Model two: Contrasting Documented Techniques*

To address the differences between the close ended well-defined problems and complex problems, five different documented techniques have been researched. They include; academically researched, systems, individual instinct, individual character and individual thinking.

**Technique One: Academically Researched**
The category, “Academically Researched”, concerns complex problem solution techniques that have been formally integrated. These strategies can be from Fortune 500 companies who have been successful in the usage of strategy or from CEO’s who were able to change their company’s downward spiral into a great success. *Blue Ocean Strategy* is an academically researched approach that investigates the 150 strategies of 30 companies over 100 years. The authors researched the idea that for industries to succeed, they must create a “blue ocean”. This blue ocean is an untouched market space where they can achieve unprecedented growth. This allows companies to avoid competition and “red ocean” areas where financial success is limited.

Finding the “blue ocean” is solving a complex problem because the industry must solve a problem that has never been solved before, so there are no limited precedents available. This strategy is discussed briefly in history classes when teaching the industrial revolution and the growth of US industries such as Ford and Rockefeller Oil Company. Both companies started in a market space where competition was non-existent. However while these events are briefly mentioned and no obvious connections are made to apply this strategy in a modern industrial setting. In one of the Fortune 500 interviews, many engineers mentioned taking required classes that educated students in learning the most successful skills in their work environment.

*Possibilities for Classroom Intervention:*

By implementing a course that teaches academically researched strategies to students interested in entering an industrial setting, and present problems with almost no precedents or existing data, students can practice solving complex problems with academically researched strategies.

**Technique Two: Systems**

Systems is a category that focuses on the process in which a solution can be achieved. During the interviews at the Fortune 500 companies, this was their most common technique in solving complex problems that arose in the process of forming a product. The systems applied typically start with a new team or an already existent team brainstorming for a possible idea to solve complex problems. Then the groups splits into specialized teams such as engineers or designers and then work on systems to make the idea reality. *Winning at New Products* gives a “game plan” on how to form the master strategy for new products using systems. In other words the perfect system for industries in order to have new successful products. The book starts with finding ideas, and then picking the right idea, next specifies the idea into a project, then moves on to picking the right project, further defines the product, tests the product and then finally enters the market. If time is not spent carefully planning the systems for all the necessary steps, there is a high rate of failure due to the lack of sufficiency in the system. *Winning at New*
Products shows a pertinent example of a system misuse when discussing a company that had a brilliant idea for a printer and did develop the technology, but did not sufficiently test the product for consumer needs and failed in market.\textsuperscript{7}  
Classrooms do have systems in order to solve problems, however they most often are for close ended well-defined problems. For example a student may be asked to form a buffer solution after being given a pH, a volume and a short list of possible solutions and solids. They have been taught Henderson-Hasselbach equation and the ability to use Ka values. The student has a system to use to form the buffer, but is was for a close ended well-defined problem.  

Possibilities for Classroom Intervention:  
In order for the classroom to teach systems in the way industrial settings have been applying them, case studies can be used. By teaching students case studies of systems from industry, they can identify a working system and an insufficient system. They can then write an essay and be measured on their comprehension of the systems and their critical thinking skills.\textsuperscript{3, 19}  

Technique Three: Individual Character  
The category individual characteristic is about the individual elements that can be used to solve complex problems. These characteristics can be personality traits, such as optimism or it can be an aptitude, such as empathy or patience. Specifically, empathy has the connotation of being the same as sympathy, but looking at the definition that is inaccurate. Empathy is the ability to feel with someone rather than for. Empathy can allow people to imagine a situation from another perspective. This can lead to insight and a whole to perspective on a problem or a solution.\textsuperscript{15}  
In industry this can help point out flaws or insufficiencies in products that one may not have noticed from their original view. It can make a product more marketable or attuned to the consumer, solving a complex problem on how to appeal to a large diverse market.  

Possibilities for Classroom Intervention:  
In schools this step of learning is often left to the student to learn through social interactions and it is random if the student learns beneficial characteristics. In order to decrease the randomization, a project can be introduced to students where each teams up with a partner and lists an admirable characteristic from the other they don’t have. This may be punctuality, perseverance or curiosity. Next they spend a semester using the new characteristic and observes how their lives changed by implementing one new beneficial characteric to develop their own individual strengths. Then they write an essay or report on how their lives changed and what new characteristics they would attempt to take on next.\textsuperscript{3}
Technique Four: Individual Thinking

Individual thinking is a category that focuses on the beginning steps of solving complex problems. These beginning steps are crucial as without the willpower to brainstorm a new idea, nothing new would be developed. Many people turn to motivational speakers to learn how to approach problems and how to start motivating oneself effectively. Tony Robbins is a famous example of a motivational speaker who talks about how to make oneself an efficient and happy human being through changing how one thinks. In one of his books *Awaken the Giant Within* he discusses how beliefs can influence the way one's life will turn out. If you believe that you can be successful and can pull certain references of yourself to support your belief, you can make personal breakthroughs to be successful.\(^1^7\) By not having all the components to a problem, one must start with the willpower to come up with an idea. If one thinks negatively and believes their solutions are failures, nothing will be accomplished. The industrial setting needs to have engineers who have the willpower to brainstorm their own ideas and present them as possible successful solutions to complex problems.\(^1^8\) Obviously this kind of individual thinking exists. It is however not trained or cultivated. It is let to chance. No new ideas would arise to solve complex problems that industrial settings face, which would lead to the collapse of the industry.

In classrooms, individual thinking is used when group projects are assigned. The group must complete the project with their ideas, but it must fit within the constraints of the assignment. However, many group members do not attempt to discuss their own ideas, as they feel inferior to the rest of the group. This type of thinking leads to students avoiding the first steps to solving complex problems.

*Possibilities for Classroom Intervention:*

In order to teach a more efficient ways of individual thinking, students can complete an individual assignment, where they must understand what is conflicting with their will power. Then they must figure out their own way of solving said conflict in order to improve their thinking. In order to record this change, the students can keep a journal where they write what goals they have in order to change the way they think.\(^1^7\)

Technique Five: Individual Instinct

The category individual instinct is a personal strategy that often comes from experience or a gut feeling. This is the the only technique a student is left with if not exposed to other techniques or experience. In many cases most students are not exposed to enough experience to trust their gut feeling. This type of technique if often found in entertainment such as movies and books, authors often have the main character use their “gut” to determine the solution to their complex problem they don’t have time, tools or resources to solve. Famous examples include *Men in Black 3*, where Agent K randomly suggests going to go eat pie in order to figure out the next move and
was able to receive vital information randomly.\textsuperscript{12} \textit{Shot in the Dark} utilizes this gut-instinct strategy as well, when Detective Clouseau is trying to solve a murder mystery. After repeating the phrase “Nothing matters but the facts” and going through all the facts with his assistant it is obvious that the maid committed the murder. However Clouseau decides that the maid was protecting someone and his reasoning was instinct.\textsuperscript{2} Classrooms often teach gut-instinct as a multiple choice answering technique. If a student is stuck on a question, they are taught to trust their instinct because their instinct is their subconscious mind.\textsuperscript{13}

\textit{Possibilities for Classroom Intervention:}

In order for a more constructive use of individual thinking, students can observe literature and see where gut-instinct has worked and where it hasn’t to solve complex problems. They should find that when gut-instinct did work, that the character had great prior experience in tackling a certain kind of complex problem. When it did not work the character was often a younger or new to a particular situation and did not have the experience to trust the gut-instinct.

\textbf{Table of Teaching Technique Summary}

<table>
<thead>
<tr>
<th>Teaching Technique Names</th>
<th>Description</th>
<th>Example for Possibilities for Classroom Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academically Researched</td>
<td>Builds upon already researched strategy approach to problem solving.</td>
<td>\textit{Blue Ocean Strategy} is an academically researched approach that contains the strategies of 30 companies over 100 years. \textsuperscript{9}</td>
</tr>
<tr>
<td>Systems</td>
<td>Focuses on the process in which a solution can be achieved. Corporate structure development, market systems are common.</td>
<td>\textit{Winning at New Strategies} discuss using systems in order to find ideas, pick the right idea, specify the idea, pick the right project, define the product, test the product and enter the market.\textsuperscript{7}</td>
</tr>
<tr>
<td>Individual Instinct</td>
<td>Strategy that often comes from experience or a gut feeling.</td>
<td>\textit{Men in Black Three} and \textit{Shot in the Dark} are famous examples of the main antagonist using their gut. Agent K randomly suggest getting pie and was then able to solve the complex problem. Detective Conan used only instinct to determine the murderer despite the facts all pointed to a different answer.\textsuperscript{2} \textsuperscript{12}</td>
</tr>
</tbody>
</table>
Individual Characteristics  

The individual traits that can be used to solve complex problems often brought to life with successful examples

A Whole New Mind describes empathy to be what allows people to imagine a situation from another perspective. This can lead to insight on a complex problem. In industry this can help point out flaws or insufficiencies in products that one may not have noticed from their original view.  

Individual Thinking  

Focuses on the beginning steps of solving complex problems, enabling the student to see the opportunity for success.

Awaken the Giant Within he discusses how beliefs can influence the way one's life will turn out. The industrial setting needs to have engineers who have the willpower to brainstorm their own beliefs into ideas and present them as possible successful solutions to complex problems.

<table>
<thead>
<tr>
<th>Individual Characteristics</th>
<th>Individual Instinct</th>
<th>Individual Thinking</th>
<th>Academically Researched</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.72</td>
<td>-0.06</td>
<td>1.00</td>
<td>1.22</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.96</td>
<td>0.94</td>
<td>0.91</td>
<td>0.88</td>
</tr>
</tbody>
</table>

The survey’s purpose was to collect the preferences on the five teaching techniques reviewed in this paper and listed in the chart above. Responses were solicited from academics professionals across the U.S.. The respondents were asked to rank the five techniques by selecting strongly agree, agree, neutral, disagree or strongly disagree as to their appropriateness for use in a classroom setting. The survey in Appendix 1 was distributed by email to individual respondents. The results address which technique was preferred. The range from 2 to -2 was used to numeralize by rating strongly agree to 2, agree to 1, neutral to 0, disagree to -1, and strongly disagree to -2 ranking. This rating allowed for the above averages to be calculated and the standard deviation. By analyzing the results, individual instinct was given the lowest ranking.

Results

This table lists the results of the survey tool applied.
Individual characteristics, individual thinking, academically researched and systems were greater than individual instinct at or above a 99% confidence level. Statistical power calculations indicate a 90% chance of detecting this difference at a 95% confidence level with a base size seven times smaller than used in that used. 105 surveys were conducted. The results are statistically robust. By using the results, it can be concluded that the classroom interventions for individual characteristics, individual thinking, academically researched and systems are seen as the most appropriate choices for implementation in the classroom in order to prepare learners to solve complex problems. Perhaps and individual instinct can be used at a minimum, as a negative control.

**Conclusion**

The purpose of this paper is to present observations and information that can prepare learners to solve complex problems. Through research the major problem was defined as a lack of complex problems in the classroom setting. However, now with the survey results and research; individual thinking, academically researched and systems have been found to be the best techniques to teach in the classroom setting. Many entering the industrial setting are undergraduate students who have been through close ended well-defined problems, so now adding projects that draws the focus to solving complex problems at this stage is a place to start when first implementing these techniques. Eventually, the techniques should be implemented further back in the education system, as to increase the comprehension of the techniques and be able to apply them in the engineering education industrial settings.

**Reference**

1. *AP® United States History: Including the Curriculum Framework.* The College Board., 2015
5. *Calculus Calculus AB Calculus BC Course Description.* The College Board., 2012


Appendix 1 Survey Questionnaire [Question order randomized for each respondent]

Teaching Techniques

In order to prepare learners for solving complex problems in the industrial setting, which of the following categories do you agree should be prioritized in a classroom curriculum? In total there are five given categories represented by each of the following questions; individual characteristics, thinking, instinct, academically researched and systems.

Academically Researched

The category academically researched builds upon already researched strategies. For example Blue Ocean Strategy is an academically researched book that contains the strategies of 30 companies over 100 years. These strategies can be studied by students.

Strongly Agree:
Agree:
Neutral:
Disagree:
Strongly Disagree:

Individual Characteristics

The category individual characteristic is about the individual elements that can be used to solve complex problems. One example would be patience which can be exercised when having to take time to perfect a solution.

Strongly Agree:
Agree:
Neutral:
Disagree:
Strongly Disagree:

Individual Instinct

The category individual instinct is a personal strategy that often comes from experience or a gut feeling. In entertainment such as movies and books, authors often have the main character use their “gut” to determine the solution to their complex problem they don’t have time, tools or resources to solve.

Strongly Agree:
Agree:
Neutral:
Disagree:
Strongly Disagree:

**Systems**

Systems is a category that focuses on the process in which a solution can be achieved. A possible one would be a corporate structure. This is where different teams are working different parts of the problem to eventually fit together into a solution.

Strongly Agree:
Agree:
Neutral:
Disagree:
Strongly Disagree:

**Individual Thinking**

Individual thinking is a category that focuses on the beginning steps of solving complex problems. An example would be Tony Robbin’s motivational speeches and seminars on eliminating what is stopping you and using the known to understand the unknown.

Strongly Agree:
Agree:
Neutral:
Disagree:
Strongly Disagree: