[Journal of STEM Teacher Education](http://ir.library.illinoisstate.edu/jste?utm_source=ir.library.illinoisstate.edu%2Fjste%2Fvol46%2Fiss2%2F5&utm_medium=PDF&utm_campaign=PDFCoverPages)

Volume 46
Issue 2 *JITE Fall*

Article 5

October 2016

Contextual Problem Solving Model Origination

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Abstract

Problem solving has become a central focus of instructional activity in technology education classrooms at all levels (Boser, 1993). Impact assessment considerations incorporating society, culture, and economics are factors that require high-level deliberation involving critical thinking and the implementation of problem solving strategy. The purpose of this study was to analyze components, sequencing, and challenges associated with technology education student identification and development of problem solving models that factor societal, cultural, and economic considerations. Additionally, this study investigated individual problem solving strategies concerning methods, solutions, and abilities. This study identified that there is no apparent effect on initial component selection of problem solving modeling whether challenged with environmental or manufacturing issues. Students highlighted problem identification as the initial phase of the developed models. Perception of technology education student problem solving ability is high, but students tend not to vary from prescribed categorical stage models that are commonly demonstrated and used in the teacher preparation program.

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Introduction

The method by which students learn, think, reason, process information, sequence operations, and determine solutions to open-ended problems has and will be continually investigated. Research concerning mental processes of students is determinedly pursued in efforts to capture higher understandings of student cognition. A 2006 study by Chrysikou conducted at Temple University suggests that problem solving is an active expression of goal-directed cognition. "Problem solving refers to a situation in which the solver develops and implements plans with the intention of moving from a problem state to a goal state within a range of constraints" (Chrysikou, 2006, p.935). Problem solving and design includes not only the enhancement of initial ideas but also associated research, experimentation, and development (McCade, 1990).

Problem solving is plainly an essential ability in our technologically advanced world. Leaders in government, business, and education have insisted on heightened emphasis on higher-order thinking skills and problem solving in both general and technological areas (Wu, Custer, & Dyrenfurth, 1996). An increased understanding of how students employ problem solving processes and their relation to absolute solutions is important to improve students' problem solving performance (Stein & Burchartz, 2006). Technology education and problem solving have an existing congruence stemming from the fact that technologies are, in many ways, a product of problem solving (DeLuca, 1991). Technological problems necessitate the application of knowledge from an array of disciplines required to effectively develop and test solutions while considering potential impacts.

Impact assessment and analysis are major considerations in critical thinking and problem solving (specifically technological problem solving). This processes of assessment and analysis evaluates the most extensive vision of issues and inquires about related benefits and deficiencies. The results assist in uncovering planned, unplanned, intended and unintended, desirable and undesirable factors (Deal, 2008). True critical evaluation of problem solving processes includes impact considerations incorporating society, culture, and economics. Porter, Rossini, Carpenter, Roper, Larson, and Tiller, (1980) indicate that social, cultural, and economic feasibility gauging cost versus benefit in its framework is a vital component of technological impact assessment and analysis. Social analysis gauges the impacts of technology on people, while cultural impact assessment involves change to the standard, values, and beliefs systems that channel and rationalize their thoughts and perceptions of themselves or group (Burdge & Vanclay, 1995). Economic analysis in technological impact assessment refers directly to potential profitability and propositions for broader interests. However, the border amid social and economic impacts in areas without quantifiable costs and benefits is ambiguous. Impact analyses generally proceed from assumed models with pre-established systematic relationships composed of elements and components that are parallel in structure (Porter, Rossini, Carpenter, Roper, Larson, & Tiller, 1980).

Among the considerations in problem solving processes specific strategies and approaches are employed. A systematic approach of arriving at a solution to a specified problem is a balanced and reflective practice that enhances outcome (Pol, Harskamp, Suhre, & Goedhart, 2009). Such systematic approaches encompass sequencing targeted tasks and mental processes in an operable and logical order. However, Moreno (2006) indicates in the work of Pol, Harskamp, Suhre, and Goedhart (2008) that instructional programs are not to directly teach students how to solve problems, but instead focus on general process steps. This prevents the development of students who simply follow procedures and allows them to further explore aspects of problem-solving that enables reaching solutions to diverse problems.

Research Questions

This research study analyzed components, sequencing, and challenges associated with technology education student identification and development of problem solving models that factor societal, cultural, and economic considerations. Additionally, this study investigated individual problem solving strategies concerning methods, solutions, and abilities. The following questions guided this study:

1. Does content (environmental and manufacturing) influence initial sequencing of problem solving?
2. Does content (environmental and manufacturing) influence placement of societal, cultural, and economic considerations in original problem solving models?
3. Do students associate problem solving with the design of a tangible artifact?
4. What are students' perceptions of personal problem solving abilities, methods, and solutions?
5. What do students find the most challenging about the development of an original problem solving model?
6. Can students generalize problem solving models to other technology education content areas?

Hypotheses were derived, where appropriate, to provide specific evaluation of research Questions 1, 2, and 3: a) There is no difference in how students presented with environmental issue challenges and manufacturing issue challenges commence with problem identification in model development; b) there is no difference in the way students presented with environmental issue challenges and manufacturing issue challenges position and sequence social, cultural, and economic considerations in design/problem solving models; c) there is no difference between students presented with environmental issue challenges and manufacturing issue challenges product design components in problem solving. Research Question 4 was evaluated through an instrument designed to determine perceptions of problem solving. Research Questions 5 and 6 were evaluated through supplemental questioning of participants.

Participants

Participants in this study were enrolled in a technology education teacher preparation program during the 2008 Fall Semester. Specifically, the participants were students in one of two courses: Emerging Issues in Technology, or Manufacturing Technology. The Emerging Issues in Technology course explores contemporary agricultural, environmental, and biotechnological topics. Students complete associated learning activities, experimentation/data collection exercises, and modeling projects. In the Manufacturing Technology course, students study product design, production system design, and manufacturing organization. Students are required to design, operate, and evaluate a classroom manufacturing system.

These two courses were selected as a result of the coordinated course offerings at the institution, separation of the content between courses, and the anticipated academic level of the students enrolled in the courses. Students in the Emerging Issues in Technology course and the Manufacturing Technology course are in the secondary level of their major and typically student teach the following semester or spring semester of the following year. Students enrolled in these courses have existing knowledge bases and experiences associated with materials and processes, energy and power infrastructures, electronics, robotics, engineering graphics, architectural graphics, and other engineering design principles and processes. Participants in the selected courses of the post-secondary technology teacher education program may have been previously enrolled, although not gauged in information and data collection for this study, in technology education at the secondary or middle grades level. Additionally, participants were not simultaneously enrolled in both courses but may have completed one of the courses in a previous semester. Table 1 and Table 2 provide more detailed demographical breakdowns of student participants in the Emerging Issues in Technology course and the Manufacturing Technology course.

Table 1.
Emerging Issues in Technology Demographics

Gender n - (%)	Male	16 - (94%)
	Female	1 - (6%)
Age Range n - (%)	18 - 20	2 - (12%)
	21-23	12 - (70%)
	24-26	1 - (6 %)
	27+	2 - (12 %)
Major n - (%)	Technology Ed.	15 - (88%)
	Tech./Graphics	2 - (12%)

Table 2.
Manufacturing Technology Demographics

Gender n - (%)	Male	13 - (72%)
	Female	5 - (28%)
Age Range n - (%)	18 - 20	5 - (28%)
	21-23	11 - (61%)
	24-26	1 - (5.5 %)
	27+	1 - (5.5 %)
Major n - (%)	Technology Ed.	10 - (55%)
	Tech./Graphics	8 - (45%)

The majority of the Emerging Issues in Technology and Manufacturing Technology student participants were male, in the 21-23 years of age category, and Technology Education majors. The two student groups in this study consist of 35 participants. Of the 35 participants, 29 were male, 23 were in the 21-23 years of age category, and 25 were majoring in Technology Education. In the teacher preparation program, students also double-major and minor in Graphic Communications. The two groups identified in the study are representative of all sole major and major/minor classifications.

Methodology

The researcher developed a research proposal, submitted and received administrative approval by the Institutional Review Board. After approval, instructor permission was requested and granted to use one agreed upon 45-minute course segment at the beginning of each course's laboratory class meeting. The researcher prepared two concise (seven slide) PowerPoint presentations. One presentation was prepared for the Emerging Issues in Technology course and one presentation was prepared for the Manufacturing Technology course. The presentations were identical in content but presented slightly different challenges. The content portion of both presentations consisted of five design/problem-solving models: 1) The Technology Problem-Solving Model (MacDonald & Gustafson, 2004), 2) The Integrated Problem-Solving Model (Wilson, 1999), 3) The Problem-Solving "Bases" (Nichols, 2004), 4) The General Problem-Solving Process (Cisco, 2007), and 5) The Engineering Design Process (NASA, 2008).

The Technology Problem-Solving Model, described and graphically represented by MacDonald and Gustafson (2004), is a cyclical process that highlights the basic features of a problem, a plan, an implementation strategy, and an evaluation. This model focuses on the representation of the stages through sketching and/or drawing. Wilson’s Integrated Problem-Solving Model begins with problem identification and concludes with a solution statement. Each of the four component parts of the model (identification, definition, resolution, and statement) are retraced if an unsatisfactory or unrefined solution is reached instead of restarting the process with initial problem identification. The Problem Solving “Bases” described by Nichols (2004) operates on the processes of rethinking, redefining, and redesigning. A key feature of this model is to build consensus and support before settling on a course of action. Assessment of effects and consequences are taken into account and adjusted before future action is taken. Cisco’s General Problem-Solving Process creates a flow of activities where facts are gathered, possibilities are considered based on those facts, and a plan is developed. Unlike many of the other models, there is a resolution stage after results are observed where major problems cease; then the process is terminated. NASA's Engineering Design Process is also represented in a cyclical formation that features the specification of design components. Criteria and constraints serve as the basis for evaluation of designs or prototypes. These models all contain unique components or features within their specified processes that encompass the predominant features in many contemporary problem solving/design models.

A component overview was conducted for each problem solving/design method by projecting the five model's graphical organization and highlighting essential process features. The Emerging Issues in Technology course was challenged to generate an environmental issue problem-solving model that factored social, cultural, and economic concerns, while the Manufacturing Technology course was challenged to generate a manufacturing issue problem-solving model that also factored social, cultural, and economic concerns.

The instructor asked students to brainstorm and develop a unique model that provided their challenges. Using two blank sheets of white lineless paper and a felt tip black marker, they had ten minutes to brainstorm by writing and/or sketching on the first sheet of paper and fifteen minutes to generate and finalize their models on the second sheet. Once all students had completed their original models, a 25 question survey instrument was distributed. The Problem Solving Inventory instrument took approximately ten additional minutes to complete. The instructor asked participants to staple their model to the survey and turn it in for evaluation.

Four students from the Emerging Issues in Technology group and four students from the Manufacturing Technology group were selected at random through course roll assignment and computerized number generation. The researcher requested that they answer four supplemental questions in an interview format:

- What did you find the most challenging about the development of an original design/problem solving model?
- What makes this a universal model given the assigned _______ (environmental or manufacturing) issue?
- Where did you position social, cultural, and economic considerations in your model (early, middle, or end) and why?
- Will your model also serve as a design/problem-solving model for _______ (environmental or manufacturing) issue?

After student participant willingness was confirmed, the eight (four in each group) selected participants were relocated into an adjacent meeting room where a digital recorder and individual stand microphones were set-up for the supplemental questioning. The students were presented with their original design/problem solving models for reference. The researcher read each question aloud to each participant in a rotational format. Participants were allowed as much time as needed to respond to each question, averaging approximately one minute and thirty seconds, before moving to the next participant. The audio recordings of the supplemental questions were transcribed and analyzed.

Instrumentation - The Problem Solving Inventory

The 25 question survey instrument was adapted from "The Problem Solving Inventory" developed by researchers at the University of Central Florida (Heppner, 1988). The initial instrument was generated and tested to assess problem solving qualities of special event professionals to be used in the development of an educational training module. The original instrument contained 35 questions with Likert-type response options ranging from 1=strongly agree to 6=strongly disagree.

The instrument was modified to include 25 questions while maintaining the Likert-type response options ranging from 1=strongly agree to 6=strongly disagree. Some statement wording was changed to target identified process problems instead of problems associated with personal difficulties as previously assessed in the original instrument.

Data Analysis and Findings

Student participant original model information, student adapted Problem Solving Inventory ratings, and student supplemental question transcriptions were entered, coded and analyzed. The sets of data were analyzed through nonparametric methods, as they do not rely on the estimation of limits describing the distribution of the variable being investigated within the population. Therefore, the methods do not require observations drawn from a normally distributed population while still allowing valid inferences about the samples.

The first hypothesis evaluated was: There is no difference in how students presented with environmental issue challenges and manufacturing issue challenges commence with problem identification in model development. This hypothesis was evaluated in Table 3 using the nonparametric Mann-Whitney test. The test statistic for the Mann-Whitney test was compared to the designated critical value table based on the sample size of each student participant group. The participant data for both sample sizes was less than 50, denoting that no normal approximation with continuity correction was necessary and the reported p-value is exact. The critical alpha value was set at 0.05 for this investigation. The p-value for the test (0.9761) was determined to be larger than 0.05, therefore, the null hypothesis failed to be rejected. The analysis of data suggests that content area has no apparent effect on the initial component of problem solving modeling.

Table 3.
Design/Problem Solving Modeling – Problem Identification

Environmental (n)	Manufacturing (n)	Diff. Est.	Test Stat.	P-value
17	18	0	305	0.9761

The next hypothesis evaluated was: There is no difference in the way students presented with environmental issue challenges and manufacturing issue challenges position and sequence social, cultural, and economic considerations in design/problem solving models. This hypothesis was evaluated in Table 4 using the Kruskal-Wallis Test. The Kruskal-Wallis Test ranks designated elements from lowest to highest in the two designated samples.

The sampling distribution for the H statistic was used to test the null hypothesis. The calculated values for the H statistic were evaluated in comparison to the critical values to determine if the null hypothesis is rejected or if there is evidence that fails to reject the claim. The H statistic is less than the critical value so the null hypothesis is not rejected. The analysis suggests that participants challenged with the environmental issue sequence social, cultural, and economic considerations in a significantly different manner than students challenged with the manufacturing issue.

Table 4.
Design/Problem Solving Modeling – Social, Cultural, and Economic Sequencing

	Environmental	Manufacturing	
N	17	18	
DF	1	1	
Median	2	3.5	
Average Rank	13.941176	21.833334	
Chi Square			6.2308598
P-value			0.0126

The final hypothesis evaluated was: There is no difference between students presented with environmental issue challenges and manufacturing issue challenges product design components in problem solving. This hypothesis was evaluated in Table 5 also using the nonparametric Mann-Whitney test. The test statistic was compared to the designated critical value table and the p-value was determined (0.0173). The analysis of data suggests that participants challenged with the manufacturing issue developed problem solving models that necessitate the design of a tangible artifact to a significantly different (higher) degree than students challenged with the environmental issue.

Table 5.
Design/Problem Solving Modeling – Tangible Design

Environmental (n)	17
Manufacturing (n)	18
Diff. Est.	0
Test Stat.	364.5
P-value	0.0173

The 25 question survey items were categorized into problem solving methods, problem solving solutions, and problem solving abilities. Ten survey items pertained to problem solving methods, seven items pertained to problem solving solutions, and eight items pertained to problem solving abilities. Table 6 provides a frequency and proportional account of the three categories for both groups. Emerging Issues in Technology student participants predominately "moderately agree" or "slightly disagree" with the statements concerning their problem solving abilities, proficiency in utilizing effective problem solving methods, and proficiency in selecting appropriate solutions when presented with a problem. The Manufacturing Technology student participants were found to answer much the same as they also predominately "moderately agree" or "slightly disagree" with the statements concerning their problem solving abilities and proficiency in utilizing effective problem solving methods. However, the participants predominately "strongly agree" or "moderately agree" with statements concerning proficiency in selecting appropriate solutions when presented with a problem. Further, an additional Wilcoxon hypothesis test was conducted to determine if there was a statistically significant difference between the Emerging Issues group and the Manufacturing

Technology group. The calculated proportional value exceeded the critical alpha value set at 0.05, therefore, failing to reject the additional null hypothesis refuting difference. Provided information supplied by this additional evaluation, it is verified that student participants in the two groups perceive statements of problem solving methods, solutions, and abilities in a similar manner.

Table 6.
Categorical Results for Emerging Issues in Technology and Manufacturing Groups

	Methods	**Solutions**	**Abilities**
Strongly Agree n – (%)	44– (11%)	19 – (9%)	36 – (15%)
Moderately Agree n – (%)	111– (38%)	53 – (28%)	93 – (40%)
Slightly Disagree n – (%)	92 – (37%)	48 – (25%)	54 – (23%)
Moderately Disagree n – (%)	42 – (12%)	42 – (22%)	33 – (14%)
Strongly Disagree n – (%)	16 – (2%)	30 – (16%)	19 – (8%)
Total Categ. Response n	305	192	235

The supplemental question interviews for the Emerging Issues in Technology group and the Manufacturing group identifies that student participants found the creation of a unique model that does not employ generic sequences as the most challenging. Additionally, steps that incorporate social, economic, and cultural considerations were difficult to design.

Supplemental Question 1 - Emerging issues student:

"The largest challenge was straying away from the models that were shown as examples. I thought that they all have universal characteristics that are necessary in any model, but to consider social, cultural, and economic impacts in all aspects of problem solving you have to start fresh. It was hard for me to develop a brand new process that would help incorporate those factors that was workable."

Supplemental Question 1 - Manufacturing student:

"It was difficult to vary from the run-of-the-mill manufacturing design problem solving models. Models have general characteristics that they (the models presented) all possess. An original way to approach manufacturing issues was difficult."

Both student groups indicated that models could be considered universal by their general and broad nature. Adaptability in a model is considered a necessary component to be applicable in a variety of situations and applications. The rationale for designing each model to be inclusive was the broad challenge presented.

Supplemental Question 2 - Emerging issues student:

"They are generalized steps. They are not specifically geared toward targeted problems, but more general issues. This makes it adaptable to other areas."

Supplemental Question 2 - Manufacturing student:

"This (the student's original model) was made to be very general for the purpose of solving not only specific manufacturing problems but general manufacturing problems. The more specific you get, the less it applies. Using this approach makes it very much universal."

Students have a tendency to position social, cultural, and economic considerations in multiple positions throughout their problem solving models. Recurring consideration and reflection of social, cultural, and economic factors are present. This permits potential and actual impacts of the anticipated/final solution to be evaluated.

Supplemental Question 3 - Emerging issues student:

"I put economic, social, and cultural considerations in two places - one at the top and one at the bottom. Economic, social, and cultural considerations appear in my model while you generate solutions and after you define the problem. This allows you to consider impacts during the development phase. Additionally, after the selection and implementation of a solution, these should be considerations to properly evaluate effectiveness. This allows you to not only predict these impacts but also observe them."

Supplemental Question 3 - Manufacturing student:

"Social, economic, and cultural considerations were placed early because they are an extremely important part of the process. They appear so that through the rest of the process, they are reflected. They were also placed at the end to check the solution for suitability."

Students in both the Emerging Issues in Technology group and the Manufacturing Technology group indicate that their models could also serve as a design/problem-solving model for environmental or manufacturing issues. These responses primarily reference earlier individual statements from Question 2: What makes this a universal model given the assigned _______ (environmental or manufacturing) issue?

Discussion and Conclusions

This study identified that there is no apparent effect on initial component selection of problem solving modeling whether challenged with environmental or manufacturing issues. Students in both groups frequently highlighted problem identification as the initial phase of the model. By the strict definition of problem solving, the process begins with the onset of the problem or a “problem state”.

Overall, participants challenged with the manufacturing issue developed problem solving models that necessitate the design of tangible artifacts. Prototypes and physical artifacts of learning through problem solving are considered to be important components for manufacturing students in the teacher preparation program. This information carries over into curricula content and process considerations, spurred by student expectation.

Student participant problem solving inventories provided information that the two groups perceive statements of problem solving methods, solutions, and abilities in a similar manner. Based on the data analyzed in this study, it is concluded that the student participants’ problem solving perceptions are not considered separated or dissimilar, eliminating the potential that student participant groups have strongly varying perceptions of problem solving methods, solutions, and abilities. Student perception is relatively high in problem solving. Repeated successful problem solving and design experiences in previous coursework in secondary education and in the post-secondary teacher preparation program surely have heightened problem solving perceptions. However, beyond the scope of this study lies open-ended investigation and structured design experiences with minimal criteria and constraints. The supplemental questioning uncovered that student participants find it difficult to vary from prescribed models that are commonly demonstrated and used in the teacher preparation program. Based on the indicative evidence in this study, this has been identified by the researcher as an area warranting future investigation.

Technology education integrates problem solving methodology into teaching and exploratory practices. Problem solving has become a central focus of instructional activity in technology education classrooms at all levels (Boser, 1993). Impact assessment considerations involving society, culture, and economics are factors that require high-level deliberation involving critical thinking in not only the generation of problem solving models, as in this study, but also the approach and implementation of problem solving strategy.

Problem solving strategy and sequencing of problem-based operation must persistently be evaluated. More research should be conducted on early actions of students within problem solving processes. The findings from this study suggest that a general problem solving model can serve for sets of categorized content in technology teacher preparation programs. The data collected and findings from this study leave the researcher with two main questions: 1) Will a standard problem solving format work for all students? 2) If yes, is it a cross-disciplinary approach? The principal problem-solving approaches in K-12 curriculum in the United States define and solve problems focused on social needs using a cross-disciplinary approach (Black, 1998). This technology and society approach engages in the study of technological innovation as it associates with social change. Technology education has the potential to serve as the catalyst and integrator for cross-disciplinary problem solving studies.

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