Technological Literacy for K-6 Teachers: How Things Are Designed and Work

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Introduction

The 21st Century teacher must be prepared to provide students with the technological literacy they will need to assume the responsibilities of citizenship in a technologically complex, democratic society. The International Technology Education Association (ITEA) has published comprehensive “Standards for Technological Literacy” \cite{ITEA2000} in grades K-12. These standards set benchmarks for students in terms of the level of technological literacy (the ability to use, manage, assess and understand technology) expected at each stage in the student’s K-6 experience (ITEA, 2000, p.9). If teachers are to help students meet these benchmarks, they must have a comprehensive understanding of the broad spectrum of technology from how things work and why to the socio-economic, environmental implications and ethical questions related to the use of technology.

In most universities in the United States the preparation of teachers is perceived as the domain of colleges of education. However, the expertise in “technological literacy” is multi disciplinary thereby offering opportunities for collaboration with potential for enriching undergraduate and professional preparation of future teachers. A recognition of the critical role of teachers and the cross disciplinary nature of “technological literacy” has prompted a College of Education - College of Engineering collaboration at San José State University.

A team of six faculty members from the Colleges of Education and Engineering, including the deans of these colleges, is designing a course in technological literacy for pre-service K-6 teachers. The course, which features hands-on laboratory experiences, emphasizes how common, technologically-based systems, processes and products work and how they are designed.

The major learning goals of this innovative course are for students in the course, who are pre-service teaching majors, to demonstrate:

1. Knowledge of the K-12 standards related to technology

2. Understanding of the processes involved in the development and implementation of various technologies

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3. Understanding of the ethical, cultural and societal issues and implications related to technology

Learning Goals

The course design team has developed six learning goals for the technological literacy course. Beginning with elements of engineering analysis and how things work, the student then participates in at least one engineering design project, learns essential communication and presentation skills, considers ethical and social issues associated with the use of technology, and relates all of these elements to the national technology standards.

Learning Goal 1: Students Will Learn Elements of Engineering Analysis

An important element of what engineers do is analysis. This goal addresses several aspects that constitute engineering analysis. Included are the design and implementation of experiments, representation and analysis/interpretation of data, and formulation of conclusions. Emphasis is on translating the statement of a real-world problem or question into a meaningful experiment, conducting the experiment to obtain experimental data, considering how to represent the data (descriptively, graphically, in tabular form, …), and then interpreting the experimental results and formulating conclusions.

Student Learning Objectives

Students should be able to:
1a.) Translate a problem statement or a question into an appropriate experiment(s) to provide data that illuminates the nature of the problem and suggests solutions.
1b.) Successfully conduct the experiment and obtain the information/data desired.
1c.) Demonstrate the ability to select an appropriate representation of the data/information obtained from the experiment.
1d.) Successfully use necessary tools, e.g., computer applications, to represent and enhance the data.
1e.) Interpret the data representation and draw appropriate conclusions.
1f.) Demonstrate the ability to use the conclusions drawn to re-design the experiment, if necessary, to provide additional data to further enhance understanding of the problem and its solutions.
Example: Analysis of Campus Parking Capacity

Question/Problem: Does the campus parking garage have adequate capacity to meet the need of students, faculty and staff?

Secondary Questions: If I want to maximize my chances of getting a parking space in the campus garage, at what hours of the day should I arrive?

An Approach:

A. Develop an input-output count of vehicles entering and leaving the garage. What needs to be counted? For how long? How many people will be needed to collect the data? Can we collect data for just one day, or do we need to do it for every day? Or should we narrow the problem/question to: Does the parking garage have adequate capacity on Mondays?

B. Organize a team of students with appropriate equipment to conduct the input-output count. What needs to be counted? How are various situations dealt with, e.g., a car enters the garage, finds no empty space and leaves?

C. Represent the data. Probably want a graphical representation. What are the possibilities:
   a. Word description of what the traffic flows look like?
   b. Pie chart of the amounts of net input over various parts of the day?
   c. Plot of the time history over the day of the net number of vehicles entering the garage?
   d. Bar chart of the net numbers of vehicles into the garage over various time periods in the day?
   e. A table hour-by-hour, for example, of the net number of vehicles entering the garage?
   f. Other?

D. Analyze the data and draw conclusions. Does the garage ever fill completely? If so, during what time periods? When, if ever, are there spaces available in the garage? Is an additional garage needed? How do you justify, other than convenience, the additional garage. What are the environmental impacts of a new garage?

E. Are there limitations to the experiment? For example, if it was done on one Monday to determine traffic patterns, how do we know if the data obtained is representative of the traffic patterns for all Mondays? Can we use the conclusion about a specific Monday to extrapolate conclusions about other Mondays or other days of the week?

Learning Goal 2: Students Will Learn How Some Familiar Engineered Products Work

As young people, many engineers became familiar with and excited by technology by taking apart and putting together commonly found household products. In addition to the
challenge of accomplishing the disassembly and reassembly (with no parts left over and without damaging the product) excitement is engendered by figuring out how the product actually works. This “How Do Things Work” learning goal is to be achieved by providing hands-on laboratory sessions disassembling and reassembling modern technological systems that directly affect human life, or developing small-scale representations of large and complex systems.

**Student Learning Objectives**

2a.) Disassemble and reassemble a small electrical appliance and be able to identify the power supply, the power train, and the different mechanical and electrical components.
2b.) Manually collect data from an experiment, and tabulate, process and graph the data using a computer spreadsheet program.
2c.) Explain the technological aspects of different real-world applications of technology.
2d.) List the major components of a variety of real-world applications of technology.

**Examples**

Disassemble and identify the components of a desktop computer and peripheral hardware
Perform reverse engineering on an electrical appliance
Identify the functional components of a networking system for PCs
Disassemble an internal combustion engine and a power drive and identify the key components
Construct and test a simplified electrical power grid and distribution system

**An Approach:** Construct and Test a Simplified Electrical Power Grid and Distribution System

A. A representation of a power grid will be built prior to the class. This will include a hand crank power generator, various resistors and circuits. Student will provide the power for the grid via the hand crank and monitor the current and voltage of various circuits as different resistors are connected.
B. Collect data on the current and voltage of specific circuits during the operation of the lab. How does the grid react to being heavily loaded? Is there a peak power that the generator can produce?
C. Represent the data. Tabulate and graph the data to show power production and consumption.
D. Analyze the data and draw conclusions. Which resistors make the largest influence on the grid? How does load-sharing influence the grid?
E. Extrapolate to the real world. Perform an online research project to answer some of the following:
   a. What are the power generators for California?
b. What is the maximum power that these generators can produce?
c. What are the users?
d. What are the environmental impacts of power generation?
e. What are the economic benefits?
f. How does staggering the usage of electrical power benefit everyone?
g. Why does the power grid use rolling blackouts?

**Learning Goal 3: Students Will Investigate Approaches Used in Engineering Design by Carrying Out a Design Project**

Our quality of life in the last century has improved tremendously primarily due to the design work of engineers. Design, in the engineering sense, is the creation of a commodity for the benefit of mankind. In more complex terms, engineering design is the process by which ideas, tastes, prejudices, basic scientific principles and available resources are weighted and combined (synthesized) into a well defined plan (specification) for the eventual construction of an object, process, or a system. This goal addresses engineering design with emphasis on the design process. The starting point is the identification of a need (e.g., an automobile is very noisy), followed by the specification of design requirements, constraints and criteria, research, brainstorming, analysis of potential solutions, development and testing of models, and finally selecting the best concept and implementing it. The end result will be a product that addresses this need and solves the problem (in this case a muffler).

**Student Learning Objectives**

Students should be able to:

3a.) Develop a flow chart of, and describe, the design process.
3b.) Translate a “real world” problem / need into practical (engineering) terms (i.e., specify design requirements and constraints).
3c.) Develop criteria for evaluation (i.e., how do you select the best concept among several that meet all design requirements and constraints?).
3d.) Search for, and study existing solutions (reverse engineering).
3e.) Look for, and analyze alternative solutions.
3f.) Make decisions considering the trade-offs between the various solutions.
3g.) Develop final specifications.
3h.) Communicate the results orally and in writing.

**Example: Design of a Coffee Cup**

**Problem / Need:** How can I keep my coffee hot for a relatively long period of time (a) without spending a bundle of money on fancy stainless steel cups, (b) without hurting the environment by dumping paper or styrofoam cups every time I drink coffee, (c) with a cup I can make at home, and (d) will last a lifetime?
Approach:

A. Specify the design requirement(s), constraints, and criteria (measures of merit). Design a cup that keeps coffee at or above 75°C, 20 minutes after pouring (requirement). Use only styrofoam chips, plastic wrap, duct tape, cardboard, and aluminum foil to insulate an 8 oz. tin cup (material constraints). The cup should not cost more than $5 (financial constraint). The “best” cup (among the several that might be developed) would be the one that keeps coffee at the highest temperature 20 minutes after pouring (measure of merit).

B. Search for and study existing solutions. What kinds of coffee cups are available (paper, styrofoam, glass, tin, ceramic, stainless steel, plastic, insulated, with and without cover)? How well do they perform? Which one is the best and why?

C. Brainstorm different ways that you can combine the materials you are allowed to use, to best insulate your tin cup.

D. Analyze potential solutions. Start by analyzing your test results from step B. Make a table showing coffee temperature for each cup tested, at 30-second intervals. Plot temperature as a function of time for each cup. Superimpose all the curves on the same graph for easy comparison. Are these curves in agreement with theory (Newton’s law of cooling)? If yes, what is the cooling constant for each cup? If not, why not? How many different methods can you use to estimate the cooling constant for each cup? Which method is the most accurate? Can you predict how your proposed design will perform compared with the existing cups?

E. Develop and test two or three models. Do your predictions match your test results? If not, why not?

F. Select your “best” cup. Develop detailed 3-view scaled drawings and final specifications, along with some description of your design, so that anyone interested can make the cup on their own.

Learning Goal 4: Students Will Use Technology Appropriately to Effectively Communicate and Present the Results of Their Inquiry-Based Project

Communication and presentation skills are vitally important for teachers at all levels. Prospective teachers need multiple opportunities to practice communication and presentation skills across disciplines and before a variety of audiences. In this class, each student will design and guide appropriate and instructive collaborative projects that provide opportunities to practice problem solving, communication and team skills. Each student will have the opportunity to showcase presentation skills, based on projects surrounding the use and understanding of technology in terms of how things are designed and work. This includes the translation of raw data from project findings, scientific approaches and the appropriate use of technology to “teach” colleagues in the class.
**Student Learning Objectives**

Students should be able to:

4a.) Use Microsoft PowerPoint and other presentation software to create a presentation on their inquiry-based project.

4b.) Effectively use graphs and charts to clearly represent the findings from their inquiry-based project.

4c) Communicate and collaborate effectively with teammates (by setting goals, managing their time, resolving conflicts, delegating tasks, making critical decisions, etc.) in the process of solving technology-related / engineering problems.

4d.) Use effective instructional strategies, such as clear and engaging presentations, proper demonstrations, facilitation of group discussion etc. to present the results of their inquiry-based project.

**Learning Goal 5: Students Will Develop an Understanding of the Ethical, Political, Socio-Economic, Cultural and Environmental Implications of the Uses of Technology and Their Responsibility Related to These Issues.**

The 21st Century teacher must be prepared to provide students with the technological literacy they will need to assume the responsibilities of citizenship in a technologically complex, democratic society. Prospective teachers will study the implications of various technologies (e.g. biotechnologies, agricultural, medical, energy, power, information, transportation, manufacturing and construction) related to the quality of life in our global community. They will learn to discern the difference between valid and invalid information in order to make decisions that support the greater good.

**Student Learning Objectives**

Students should be able to:

5a.) Analyze the environmental impact of the various technologies used in our modern world and address any concerns that may arise as a result.

5b.) Analyze the socio-economic impact of the various technologies used in our modern world and address any concerns that may arise as a result.

5c.) Analyze the legal, political and ethical implications of the various technologies used in our modern world and address any concerns that may arise in the process.

5d.) Recognize their responsibility in the decision-making process of a democratic society and articulate appropriate solutions, based on valid
evidence, to environmental, socio-economic, legal, political, and ethical problems that arise from the use of technology.

**Learning Goal 6: Students Will Develop an Understanding of State and National Technology Standards and Be Able to Relate Them to Curricular Issues in K-8 Classrooms.**

The purpose of state and national standards is to guide teachers as they develop curriculum intended to ensure equal access to rich curricular learning opportunities for all students. The state and national standards highlight the comprehensive nature of technological literacy. Knowledge of the national and state technology standards informs teachers’ practice as they work to integrate all aspects of technology across disciplines within the curriculum.

**Student Learning Objectives**

Students should be able to:

6a.) Identify aspects of state and national technology standards in their inquiry-based projects.

6b.) Incorporate issues related to technology in the K-8 curriculum.

**Implementation**

The course builds on the successful course for first-year engineering students at San Jose State University, “Introduction to Engineering”, but is tailored to the needs of aspiring K-6 teachers. The course will be team taught by Engineering and Education faculty members and ancillary benefits will be the improved understanding of technology by College of Education faculty and enhanced knowledge of how students learn by College of Engineering faculty. A pilot of a slimmed-down version of the course will be offered in summer 2002 to in-service teachers for continuing education credit. The results of this pilot effort will be assessed in fall 2002 and a revised, full-length course will be offered in the spring of 2003 to pre-service K-6 teachers. The full-length version will be offered in summer 2003 to in-service teachers and then, subject to enrollment demands, to all pre-service teachers beginning in the fall of 2003. Depending on success and enrollments, we hope eventually to offer the course as an approved general education course available to students throughout the University.

**Reference**