

# Teaching Engineering to K-12 Students Using Role Playing Games<sup>1</sup>

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## Abstract

There is a strong need for more well trained technically competent individuals in today's modern society. However, there is insufficient coverage of engineering and technology in our school system and many of our K-12 students do not consider engineering and technology as career options. To rectify this situation, we need to introduce our students to engineering practice, concepts, and ideas as early and as extensively as possible. Unfortunately, these students do not have the background to understand these topics as traditionally presented. We propose the use of role-playing to teach K-12 students ideas from engineering fields such as computer engineering, control engineering and power systems. We review the history and literature of role playing and its application to science education. We explain the benefits of role playing as a teaching paradigm and reasons why we believe it is particularly suited to teaching K-12 students about engineering. We also provide examples of role playing games that we have started to use in our school district and as part of special class for science and mathematics teachers.

## I. Introduction

The use of role playing as an instructional strategy has been part of the repertoire of teaching methodology for many years<sup>1</sup>. Originally role playing, in the traditional sense, such as in theatrical performances, was useful in helping students acquire empathy with characters (historical figures) in other times and places.<sup>2</sup> Empathy for pioneering characters in engineering and technology, e. g., Thomas Edison, can help students gain a better knowledge of applications of science such as the incandescent lamp. Role playing may also be a learning activity that helps students use reading to better understand science<sup>3</sup>. Skilled elementary teachers as well as some secondary teachers have generally used skits, plays, newscasts and other scenes often associated with the performing arts in two main ways. First, to engage and motivate students when new topics or units of instruction are begun by the teacher. And second, to provide redundancy and reinforcement in completed topics. Role playing provides the same benefits when introducing students to applications of the same scientific principles in current or future technologies.

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Although traditionally more common in elementary school instruction, social studies and English classes, role playing may be useful in secondary science classes as a way of introducing and familiarizing students with difficult, abstract or complex concepts in biology and the physical sciences. Because students generally find role playing to be memorable, teachers can use it to help students construct more realistic understanding of the nature of science<sup>4</sup>. Students who learn through role playing and other realistic learning strategies, e. g. field trips, are known to have better recall of the information<sup>5</sup>.

In addition to learning the intended concepts and principles, role playing enactment of real life situations promotes the development of critical thinking skills, and humanizes science by discerning its importance to everyday life. It can also develop importance skills needed in the "real world," e. g., teamwork, collaborative learning and effective communication. Role playing activities may be divided into four stages<sup>1,6</sup>:

- 1- Preparation and explanation of the activity by the teacher.
- 2- The classroom preparation of the activity
- 3- The enacting of the activity (the role playing) by the class.
- 4- The discussion of the enactment known as *debriefing*.

This type of hands-on instruction is supported by the educational research in learning theory and cognitive development. According to Piaget<sup>7</sup>, students accommodate and assimilate new information better when they have concrete educational experiences. If the educational experiences are prior to teaching abstract concepts and are related to ideas that the students already understand (advanced organizers and scaffolding), the students are better able to assimilate the new information with what they already know<sup>8,9</sup>. Role playing provides social interaction as well as real life experiences, both of which are necessary if students are to construct meaning from their learning<sup>10</sup>. Role playing may help students find personal meaning within their social world and to resolve personal dilemmas with the assistance of social groups<sup>6</sup>. Difficult science and technology concepts in chemistry, physics, and their engineering applications, may also be more readily understood if they are first introduced in a concrete activity such as role playing. Research also indicates that the use of concrete and interactive activities, e. g., role playing, as culminating teaching strategies, after students have some prior knowledge of abstract concepts, may be even more effective in helping students understand science concepts<sup>7</sup>. Furthermore, research also indicates that students learn by teaching concepts to others (inter group learning). The use of cooperative learning as a teaching strategy supports the idea of inter group learning<sup>11</sup> and role playing is an excellent example of inter group and interactive learning.

## II. Role Playing Examples in Science

The literature is replete with examples of the use of role playing in the sciences. In general, they cover the following areas, and science may be the main component or just one of several. 1. Public policy issues in science. 2. Interdisciplinary curricula, including the sciences, especially environmental science as one component. 3. The traditional sciences of biology, chemistry and physics, and 4. Environmental problems and or issues based on a knowledge of the environmental sciences.

For example, in biology, students often find the study of DNA and protein synthesis to be abstract topics for which they have no experiences to call upon to aid them in understanding these topics. Having students act out the roles of the amino acids, mRNA codons, tRNA anticodons and ATP molecules to form a DNA sequence can give them a concrete idea of how the molecules are sequenced and formed.<sup>12,13</sup>

Another example of role playing in biology is found in the important topic of evolution. Using the historical Oxford Debate between the sympathizers and opponents of Darwin in 1860, students role play the typical behavior and attitudes of the main characters in the debate. The students are given sufficient time to work collaboratively in groups to address the characters and to create appropriate responses for expected questions after the role playing. The students do not learn the lines of the characters word for word so creativity will not be stifled. The results of the role playing indicate that when students take an active part in the construction of knowledge they are more likely to gain true a true understanding of the learning content than students who learn as passive observers in the teaching process. To be active and defend the views of the their character, students need to have the proper understanding of the relevant biology concepts. Furthermore, they need to understand the main thrust of Darwin's Theory of Evolution. In this example, the role play is not as effective unless it comes at the end of the lesson after students have acquired prior knowledge of evolution.<sup>6</sup>

In the physical sciences, the use of role playing may be useful to help give students a concrete idea of the abstract concepts needed to understand atomic structure. An example that may be used in a middle school physical science class is described in detail. In middle school physical science class, students may play a game that involves the entire class to demonstrate their understanding of electrons, protons and neutrons in atomic models. The teacher must give prior knowledge of atomic structure and emphasize shortcomings of the model before the game begins since the game emphasizes two-dimensional structures, electrons that are stationary in defined orbitals and atomic mass that is integral. The teacher uses squares of construction paper to represent the three atomic particles. The symbol, name, atomic number and atomic mass are placed on the squares of construction paper and posted on the wall. Students in two competing groups must determine the number of electrons, protons and neutrons in each atom as well as the number of electrons in each orbital. Students arrange themselves to represent the number of protons, neutrons and electrons as well as the number of electrons in each orbital. After one group thinks they have correctly represented the atom they yell "stop", and then the group must explain how they determined the numbers of atomic particles. They must use correct terminology and symbols in the explanation. If the explanation<sup>14</sup> is correct, the students move on to another element<sup>14</sup>.

Role playing may also be used to help students understand the multicultural history of science as they learn science concepts. For example, instead of discussing how astronomers determined the circumference of the earth, students can act it out with a role-playing activity in which they are members of the great University of Alexandria. They can role play inquiry with Eratosthenes (born around 274 B. C.), who can be played by the teacher or a student, to determine how he measured the angle of the shadow of the sun cast in two different cities in North Africa to

calculate the circumference of the earth. In this activity, students can learn the content as well as immerse themselves in the social context of how ancient scientists lived and worked<sup>15</sup>.

#### IV. Engineering Examples of Role Playing

Role playing can serve teaching engineering and technology to K-12 students as it has served science education. The applications to science education presented in Section III serve as an example and inspiration to those interested in developing role playing games for K-12 engineering and technology education. We identify three clear modes of using role playing for this purpose and discuss them in this section.

##### IV.1 Teaching the functions and duties of various engineers and technologists

Our experience has shown that, Many students and K-12 teachers have no idea what engineers actually do. There is a strong need to inform them of the variety of activities involved in engineering so that more students can consider engineering as a career option. This lack of understanding of the duties and roles of engineers is not restricted to the general public but is often true of students of engineering. Bartz and Deaton<sup>16</sup> suggested role playing as a means of overcoming this latter problem. They used role-playing as part of an inter-course and intra-course project. Students played the roles of engineering professionals on a design team.

##### IV.2 Teaching the roles of engineers and technologist in society

As students learn concepts in science and technology they may also learn more about the interaction of science and technology with society, commonly known as STS<sup>17, 18</sup>. Role playing the part that scientists, engineers, politicians, contractors, lawyers, concerned citizens, etc. play in making and carrying out policy regarding public science, e. g., where to build highways and dams, may give students a better understanding of how science and technology is connected to society as a whole. A science program that addresses the connections and applications of science and technology with society is the SEPUP program. A culminating activity of a study of ground water pollution is a town meeting in which students role play the scientist, the engineer, the mayor, the businessman, the concerned citizen, etc to understand the pros and cons of various plans to clean up contaminated groundwater<sup>19</sup>.

STS projects encourage science teachers to work with business partners involved in the business of science and technology. One such partnership involved a middle school science teacher and her science classes with the McDonnell Douglas Corporation. In the project, the middle school science students played the role of McDonnell Douglas engineers competing for NASA contracts for rockets. The students learned about rocketry as they experienced the "real world" of deadlines, design, performance specifications and budgets to try to win a rocket contract with NASA<sup>20</sup>.

##### IV.3 Teaching the ideas and concepts underlying the operation of engineering systems

K-12 students have a deep interest in the technologies they use in everyday life. It is natural to exploit this interest to attract more students to careers in engineering and technology. The main

obstacle is that most of these students do not possess the background necessary to understand the principles underlying the engineering systems they find so intriguing. Role playing is the perfect solution for this dilemma. Role playing games where students play the roles of components of engineering systems can be developed in a variety of otherwise impregnable engineering fields.

Consider the example of the digital computer. It has now become a salient feature in most schools across the nation. Many of our students use computers for typing reports as well as for entertainment. Most of them would like to know more about how computers actually accomplish the wondrous things they use them for. Clearly, a traditional exposition is out of the question. We have successfully developed and tested a role playing game at the university of Nevada that introduces K-12 students to the major components of a digital computer and their functions<sup>21</sup>. Students play the roles of *Central Processing Unit, PCI Bus Controller, Internal Memory, External Memory, Cache Memory, Video Controller, Input/Output Devices* . Using these roles we were able to introduce them to how a computer displays a movie, processes images and use cache memory.

Another engineering example that engineering students are familiar with is the use of electricity in the home. Associated ideas that are easy to explain using role playing are: power generation, transformation to a high voltage, power delivery, transformation to a low voltage, faults, and protection. Student play the role of generator, transformer, transmission line, or phase of a transmission line, and electronic device. There are interesting possibilities for experimentation with students called upon to participate in authoring or to improvise by selecting new devices, suggesting possible failure modes, suggesting possible causes for failure with additional students playing their roles, etc.

Control systems differ from the above examples in that while students are well acquainted with many systems that could not function without control, most have never heard of a control system. While it may be possible to explain the idea of feedback and how it is used in engineering systems, students can not relate to the idea unless it is presented as part of an engineering application. Examples of applications that use control systems extensively are elevators, antenna positioning systems, automobiles, aircraft, etc. Many of those are complex engineering systems with control being one aspect of their operation to be explained to students. For example, the air/fuel control ratio and its importance in environmental regulation can be explained through a role playing game. Students can play the roles of oxygen sensor, throttle, intake manifold, cylinders, and fuel injector.

The air/fuel control example shows that understanding the operation of an engineering system is often an excellent starting point for discussions of its social, economic and environmental implications. Thus, our taxonomy of role playing games for engineering does not imply a complete separation of the three modes we identify. Use of more than one game to teach various facets of an engineering application, or use of one game combining one or more of the three modalities is clearly possible. For example, the air/fuel control game could be extended to include roles representing the environment and the individuals affected by the automobile exhaust. Alternatively, such effects can be considered as part of the debriefing following the completion of the game.

## V. Conclusion

Role playing is a promising tool in our efforts to introduce K-12 students to engineering and technology. Its more traditional use is in explaining the roles played by various individuals and the social, economic, and environmental implications of those roles. This is a valuable lesson both for students opting for a career in engineering and technology as well as for others who must learn to live in an increasingly technological society. In addition, role playing can be used to explain complex engineering systems to a younger audience or one with limited knowledge of science and mathematics.

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