Move with science and technology

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Move with Science and Technology
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Biographical notes
Robert A. Raudebaugh is the program coordinator for Technology Education at Western Washington University, Bellingham, Washington where he has taught for the last 11 years. He is a member of ITEA, Design and Technology Subsection, Council on Technology Teacher Education and currently serves on the Government Relations Committee. Professor Raudebaugh has a total of 36 years of experience in education including 13 years as a secondary classroom teacher, 7 years as a district level administrator and 16 years at the university level. He has taught woodworking, metalworking, drafting, electronics and vocational classes at the high school and middle school level. University teaching includes teacher preparation and a variety of computer aided design drafting (CADD), drafting, woodworking, electronics, and design courses.

Abstract
This paper presents a curriculum which represents a unified approach to teaching science and technology at the middle school level, particularly the 7th grade. The curriculum has a transportation theme and consists of a unifying activity challenging students to design and build a human/hybrid powered vehicle for the future. There are four smaller and relatively common activities based on the design of concept vehicles including mousetrap cars, CO2 powered cars, vehicle space frames, and radio-controlled vehicles. These smaller activities provide students with the information and skill necessary to complete the unifying activity. The curriculum is based on both the National Science Education Standards (NSES) mandate to supplement middle level science coursework with “activities that are meant to meet a human need, solve a human problem, or develop a product”. It also follows current trends in technology education to provide middle school students with activities that allow them to develop “real technological products, systems and environments” and to create prototype models. (ITEA Technology for All Americans p.38)

keywords: middle school, integrated science, technology

Introduction and rationale
It has long been a goal of professionals in Technology Education to find a way to integrate student learning of science and technology. This is evident in the theme and papers of the 96 Jerusalem International Science and Technology Conference, efforts of the National Science Foundation (USA), and the efforts of the International Technology Education Association (USA) in the National Standards Project for Technology Education. To date, there is little evidence of a successful integrated or unified curriculum for teaching science and technology. The key to a unified approach is the use of the Technology Design Process as the format for learning. Move with Science and Technology (MWS&T) is a unified science and technology curriculum with a transportation theme. Students are engaged in a design-build process involving familiar concept vehicles and research pertinent information in a scientific manner. Thus students build the middle school science ideas associated with these vehicles while developing an understanding of the design process and building technical skills.

Curriculum design
This curriculum is composed of a unifying project and four units of study. Students are hooked into the notion of vehicle design with a quick (hook) and fun safe paper car activity. They are then given the challenge – design and build a safe human/hybrid powered vehicle for the future. To help them in this unifying project, they will be guided through four instructional units of study.

Each unit challenges teams of students to design and build concept vehicles. The result of each design is presented in their design portfolio, and to the class. These vehicles are somewhat familiar middle school technology projects – a mousetrap car, CO2 car, space frame vehicle, and radio controlled vehicle. These units build hierarchical science and technology process skills and make a complete science and technology semester curriculum especially when tied together with the unifying project. The four units can be used as stand-alone units but the unifying project adds greatly to the real world authenticity of the curriculum.
Throughout the curriculum students return to the unifying project – safe human/hybrid powered vehicle of the future. As they move through this design process they employ the ideas and skills developed in the units. The prototype of their human powered vehicle should but does not necessarily have to be a working prototype. The overall assessment of this and the smaller projects is based upon their documentation of the design process, not how well their project actually works.

The organisation of the curriculum and each accompanying activity is demonstrated in the illustration in Figure 1.

Figure 1: Curriculum structure.

Conceptual development

Move With Science & Technology is guided by the National Science Education Standards (NSES) mandate to supplement middle level science coursework with “activities that are meant to meet a human need, solve a human problem, or develop a product”. (NSES p.161) Current trends in technology education include providing middle level students with activities that allow them to develop “real technological products, systems, and environments” and to create models. (ITEA Technology for All Americans, p.38)

The human powered vehicle of the future is the central challenge that ties together the four smaller design-build activities of this curriculum. These four activities build the necessary ideas, knowledge and skills required to design and build a human powered vehicle of the future, in keeping with the following National Science Education Standards (p.165):

- identify appropriate problems for technological design
- design a solution or product
- implement a proposed design
- evaluate completed technological designs or products.

An additional goal of this curriculum is the understanding of the risks associated with vehicles and how to reduce them. Students learn that “science cannot answer all questions and technology cannot solve all human problems or meet all human needs”. (NRC Science Standards p.169) MWS&T recognises that middle level students can “begin to develop the ability to assess the impacts of [technological products and systems] on individuals, society, and the environment”. (ITEA Technology for All Americans p.38) Thus the activities are designed to allow students to learn the what, how, and why of human safety associated with vehicles.

From the first activity, paper gravity powered cars, (a hook activity) students recognise the need to have an energy source that results in a force forward on their vehicle in order to cause the vehicle to move forward. The relationship between energy, force and motion will be a common theme in each of the design-build activities. The goal is to “provide concrete experiences on which a more comprehensive understanding of force can be based”. (NRC Science Standards p.149) Specifically, students are asked to describe the motion, identify the forces causing it, and the energy source in each of the design-build activities and develop the ability to do this through well connected science and technology instructional activities. These activities help students develop the concept of energy because they may “have some of the same views of energy as they do of force – that it is associated with animate objects and is linked to motion”. (NRC Science Standards p.154) In addition, students will repeatedly be asked to describe energy transfers because middle level students “improve their understanding of energy by experiencing many kinds of energy transfer”. (NRC Science Standards p.154)

The following NRC Science Standards guide students’ intended conceptual development:

- The motion of an object can be described by its position, direction of motion, and speed. The motion can be measured and represented on a graph. (p.154)
- An object that is not being subjected to a force will continue to move at a constant speed and in a straight line. (p.154)
If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalance force will cause changes in the speed or direction of an object’s motion. (p.154)

Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways. (p.155)

Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced. (p.155)

The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control, and coordination, and for protection from disease. These systems interact with one another. (p.156–7)

Another theme of MWS&T is establishing the meaning and use of scientific inquiry. All the instructional activities “engage students in identifying and shaping an understanding of the question under inquiry”. (NRC Science Standards p.144) The use of a centering design-build activity provides relevant and meaningful context so that students “know what the question is asking, what background knowledge is being used to frame the questions, and what they will have to do to answer the question”. (NRC Science Standards p.144) The following NRC Science Standards are developed in the activities of MWS&T.

• identify questions that can be answered through scientific investigations
• design and conduct a scientific investigation
• use appropriate tools and techniques to gather, analyse, and interpret data
• develop descriptions, explanations, and models using evidence
• think critically and logically to make the relationships between evidence and explanations
• recognise and analyze alternative explanations and predictions
• communicate scientific procedures and explanations
• use mathematics in all aspects of scientific inquiry.

Activity design
In order to engage students and start them thinking about designing and building vehicles, unit 1 starts with an idea-do activity: gravity powered paper cars. This first activity is a hook that can be completed in a short time period, is fun and motivational. It introduces students to both the theme of the curriculum and some basic concepts and skills. After students reflect upon this activity, they are challenged to design and build a safe human/hybrid powered vehicle for the future. Students realise they need to learn many ideas, techniques and skills in order to be successful at this challenge. The intent is to provide the motivation through a real-world problem for student inquiry to lead them into the activities of subsequent units.

The central theme for each activity is a simplified, seven-step version of the design process. This process used follows an early draft of the middle school standards for technology education posted on the ITEA Technology Education for All Americans National Standards project posted on the ITEA website. The design steps used in this guide include:

• define the problem
• gather information
• explore ideas
• develop the design
• construct a prototype
• test and evaluate
• redesign.

Students learn how to write-up proper design briefs and carry out other design activities through four smaller, more focused design-build units: mousetrap powered cars, CO2 powered cars, space frame cars and remote controlled vehicles. Each of these smaller design-build activities have four science and four technology instructional activities intended to build the concepts and skills needed to learnedly carry out the unifying design-build activity, safe human/hybrid powered vehicles. Thus students perform 16 science
and 16 technology instructional activities as well as four design-build activities in order to construct the ideas, knowledge and skills needed to carry out this major unifying design-build activity.

The notion of a future vehicle allows students to imagine and simulate eminent or inaccessible technologies into their vehicles. The choice of hybrid vehicles helps students focus on current vehicle industry research and build a vehicle which could have a much broader consumer appeal or practical application.

Important and unique aspects of this curriculum are the lessons in sketching and technical drawing built into every unit. These add up to a well thought out, overt attempt to provide opportunities and instructions for students to learn to sketch real life and make viable technical drawings. This skill development is absent from most curricula yet it is essential in many careers and can be a wonderful enhancement to one’s quality of life. Through these activities students develop the ability to use sketching as a toll to get ideas from their minds onto paper, and to explore a wide range of ideas while using sketching as a form of idea “shorthand”.

Students learn to communicate design ideas through the presentation and dissemination of their design-build activities required in each unit. These presentations have progressive criteria that, after the completion of units 2 through 5, result in a high level presentation of their unifying activity: safe human/hybrid powered vehicle for the future.

Students learn the properties of materials as they research, test, and select appropriate materials to optimise both the function and goals of their designs. These skills and knowledge are gained in each smaller unit and applied in their safe human/hybrid vehicle.

Recognising that most students need significant skill development in order to build anything they design, there are prototyping activities in every small unit that are, once again, applied to their safe human/hybrid vehicle. Students learn to select and use appropriate resources, such as measurement devices, tools, and equipment, as well as computers and computer software, to make a model or prototype of their designs. While doing so, students engage in appropriate quality and safety practices.

A portfolio provides the documentation of the design process followed in creating each concept vehicle and is the basis for assessment. To document the process, students must explain what they did for each of the seven steps of the design process along with both graphical and written evidence for each. Figure 2 is a graphical representation of a sample unit of instruction.

**Time management**

The following table shows an example of the suggested order of activity and probable number of days they will take for the unit on mousetrap powered vehicles. A day is considered a 45-minute period, and starting on a Monday, the unit could take four 5-day weeks.

<table>
<thead>
<tr>
<th>Day Number</th>
<th>Activity</th>
<th>Day Number</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intro. to Mousetrap Cars, Act.1: Defining the Problem</td>
<td>11</td>
<td>Design &amp; Build</td>
</tr>
<tr>
<td>2</td>
<td>Act.2: Measuring Force</td>
<td>12</td>
<td>Design &amp; Build</td>
</tr>
<tr>
<td>3</td>
<td>Act.2: Measuring Force (cont.)</td>
<td>13</td>
<td>Design &amp; Build</td>
</tr>
<tr>
<td>4</td>
<td>Act 3: Lever Arm</td>
<td>14</td>
<td>Design &amp; Build</td>
</tr>
<tr>
<td>5</td>
<td>Act.3: Lever Arm (cont.)</td>
<td>15</td>
<td>Act. 8 Measuring Motion</td>
</tr>
<tr>
<td>6</td>
<td>Act. 4: Human Arm</td>
<td>16</td>
<td>Act. 8 Measuring Motion (cont.)</td>
</tr>
<tr>
<td>7</td>
<td>Act.5: Sketching I</td>
<td>17</td>
<td>Testing Cars</td>
</tr>
<tr>
<td>8</td>
<td>Act. 6</td>
<td>18</td>
<td>Portfolio Preparation</td>
</tr>
<tr>
<td>9</td>
<td>Act. 7 Wheels and Axles</td>
<td>19</td>
<td>Presentations</td>
</tr>
<tr>
<td>10</td>
<td>Act. 7 Wheels and Axles (cont.)</td>
<td>20</td>
<td>Presentations</td>
</tr>
</tbody>
</table>
Unit assessment

It is important to the students that a consistent process is used in establishing their grades. An example of assessment might start out by establishing points as shown in the chart below and follow this format for each unit.

<table>
<thead>
<tr>
<th>Instructional Activity</th>
<th>% Grade</th>
<th>Points (200 pt)</th>
<th>Instructional Activity</th>
<th>% Grade</th>
<th>Points (200 pt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Problem</td>
<td>5</td>
<td>10</td>
<td>7: Wheel-Axles</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>2: Force</td>
<td>5</td>
<td>10</td>
<td>8: Motion</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>3: Lever Arm</td>
<td>5</td>
<td>10</td>
<td>Lab Book</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>4: Human Arm</td>
<td>5</td>
<td>10</td>
<td>Mousetrap Car</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>5: Sketching I</td>
<td>5</td>
<td>10</td>
<td>Total</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>6: Materials</td>
<td>5</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Lab Book is a major portion of students’ assessment. Students must demonstrate that they have recorded appropriate information from the instructional activities, as well as their personal thoughts about this information. The Lab Book is a tool for learning science and technology through writing. It may be necessary to quiz your students on simple vocabulary. An open Lab Book quiz could be used for bonus or extra-credit points as shown below.

<table>
<thead>
<tr>
<th>Lab Book</th>
<th>Percentage of this portion</th>
<th>Points if 200 point unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitions</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td>Reflective Thought</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td>Organisation, Clarity</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td>Vocabulary Quiz</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

The design-build project in the mousetrap vehicle unit has very little constraints and there will be a wide variety of designs and performances, therefore, the ability of the students to articulate what they’ve learned is especially valuable. Below is a table of suggested points for the Mousetrap car and student presentations. Notice that the ability of their car to travel a long distance is not an assessment criterion. Distance travelled is, however, important to students and awarding bonus or extra-credit points is appropriate.

<table>
<thead>
<tr>
<th>Mousetrap Car Design Build Project</th>
<th>Percentage of this portion</th>
<th>Points if 200 point unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verification of Design Process</td>
<td>75</td>
<td>45</td>
</tr>
<tr>
<td>Prototype</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Presentation</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td>Performance Bonus</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

Figure 2: Graphic representation of sample unit.