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AWIM Fuel Cell Challenge Field Test:
Executive Summary

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EXECUTIVE SUMMARY

SAE International (SAE) has produced and distributed *A World in Motion* (AWIM) curriculum challenges, in use by educators in all 50 states and Canada, since 1990. The goal of the AWIM curriculum is to promote students' science and mathematics literacy in grades four through ten in the form of authentic engineering design activities in the classroom that support a multidisciplinary, cooperative working experience.

SAE recently developed a new AWIM Fuel Cell Challenge that invites middle school students to design a car that is environmentally friendly and powered with alternative power sources and fuels. As students work in small groups, using the Engineering Design Experience (EDE) process, the curriculum addresses content objectives in the areas of science, mathematics, technology education, and language arts.

In winter 2007, SAE contracted with Goodman Research Group, Inc. (GRG) to conduct and evaluate a field test of the Fuel Cell Challenge in middle school classrooms across the country. The field test was guided by the following primary research question: *In its current form, how effective is the Fuel Cell Challenge with teachers and students under actual classroom conditions?*

Specific research questions included:

1. How well does the new AWIM challenge stand alone in its current form, and what revisions are needed to create a sustainable stand-alone package on par with existing AWIM Challenges?

2. How well does the Fuel Cell Challenge communicate the intended concepts to middle school students?

3. How does prior experience with AWIM influence use of the materials, satisfaction with implementation, perceived success with students, or overall effectiveness in the classroom?

Nineteen middle school teachers and 360 students from 11 states, in suburban, urban, and rural settings, field tested the curriculum during their regular science or technology class time for an average of five weeks or 25 class sessions. On average, teachers had been teaching science for 12 years. Just under half of the teachers (n=8) had used an AWIM Challenge with students prior to this research (Veteran teachers) and the remainder (n=11) had no prior AWIM experience (Novice teachers).

Beginning in February 2008 (Wave 1) or April 2008 (Wave 2), teachers and students conducted the Fuel Cell Challenge and completed pre- and post-surveys and feedback forms to describe implementation of and satisfaction with the curriculum. Teachers also participated in three conference calls during and after the field test. Additionally, GRG observed a subsample of classrooms during use of the Challenge activities.

KEY FINDINGS

Teachers perceived, and students confirmed, that students were engaged and responded quite positively to the Fuel Cell Challenge.

After the field test, students agreed that engineering is useful for solving everyday problems. They described more sophisticated understanding of what engineers do, such as working on new technology and employing the engineering design process. Students demonstrated increased understanding of content related to fuel cell technology, gears and ratios, and engineering design.

Teachers and students alike enjoyed the Fuel Cell Challenge activities. They were able to modify the curriculum to fit their particular needs and were primarily satisfied with the overall experience.

Field test teachers rated the Fuel Cell Challenge to be *very good*; average rating was 3.74 out of a possible 5, and students found the Challenge interesting, with an average rating of 7.23 out of a possible 10.

Both teachers and students reported that the activities were at or slightly above the students' skill levels and teachers were comfortable modifying activities as needed accommodate their own and their students' skills and abilities.

Students perceived they had *just enough* or *not enough* time to complete most activities and most felt the difficulty level was *just right* (77%) or *too hard* (18%). While some students cited difficultly understanding "*unclear*" directions, many noted they appreciated the challenging nature of the work.

Teachers' and students' prior knowledge suggests that a middle school curriculum about fuel cell technology meets an important need.

Before the field test, teachers reported they were knowledgeable about general science (average rating 5.56) and physical science (average was 5.37 out of a possible 7) and felt relatively less knowledgeable about fuel cell technology. Correspondingly, very few students had studied fuel cell technology or green design in school.

Despite, and often because of, frustration with manipulating the materials and the complexity of directions, both teachers and students ultimately perceived the Fuel Cell Challenge to be well worth the effort.

Most teachers reported spending an average of one or two hours preparing for each individual activity, and more than half of them spent more time than was estimated in the Teacher Manual to conduct each Challenge activity with students.

The majority of students reported they had either *not enough* (54%) or *enough* (40%) time for the various Challenge activities. Particular phases for which students would have preferred more time included: testing, revising, and fixing; building their vehicles, and preparing for the final presentation.

Students benefitted when teachers encouraged more frequent and consistent use of the Design Logs.

Most teachers had their students keep either team design logs (n=8 teachers) or both team and individual design logs (n=8 teachers), and encouraged use of the logs for at least half of the Challenge activities. Students who used the design logs more frequently rated the logs as more helpful. They described referring back to their logs to remember where they left off, to recall why they had made particular decisions regarding their vehicles, and to aid in preparation for their final presentations.

Teachers appreciated having all of the necessary materials and resources available to them online.

Many teachers reported a preference for a print manual, but all explained that the online version was easy to refer to and download and print as needed. Teachers particularly enjoyed the pictures of fuel cells they could show to their students.

The most useful aspects of the Teacher Manual were the information and resources directly relevant for implementation of the Challenge activities.

Particularly helpful were the student reproducible masters, resources for background and support materials, the fuel cell operation sheet and pictures, and the sections of the activity sheets that described what students would do and the purpose of the activity.

The biggest challenges noted by teachers and students related to complex instructions and materials that did not function well.

Teachers had quite a bit of difficulty with the multimeter. Knowing it was intended to provide math content; teachers suggested it could be excluded without sacrificing a strong focus on math throughout the rest of the Challenge. Teachers and students both suggested including less detail and simplifying and clarifying the instructions for Challenge activities throughout the curriculum.

Activities considered by teachers and students as most successful were those related to creating and using the fuel cell and building the car.

Teachers felt the learning objectives related to fuel cell production and operation, alternative fuels and energy transformations, and solving technological design problems were met effectively via the Challenge activities. The math related learning objectives were considered more effective by the 7th and 8th grade teachers (mean ratings of 3.14 out of a possible 5) than by 6th grade teachers (mean rating was 1.67 out of 5).

Among students, the most interesting things learned included: designing and building the car, making hydrogen and fuel cells, and seeing their accomplishment when the cars ran. Negative aspects of the experience for students were the confusing directions for some activities, the paperwork, and when some element of their car did not function properly and/or "*fell off.*"

After completing the Fuel Cell Challenge teachers better understood the engineering design process.

In particular, teachers recognized the value of initially identifying a problem, testing, and modifying. They added to their distinction between a science and an engineering activity, noting that engineering integrates various subject areas.

RECOMMENDATIONS

Based on the field test findings, GRG made several recommendations for modifications to the Fuel Cell Challenge. Most related to modifying the teacher materials to be straightforward and consistent. Each of the following GRG recommendations is followed by action steps taken by SAE upon their review of GRG's full evaluation report.

While moving toward placing the AWIM Challenge curriculum online, do not immediately eliminate the print Teacher Manual.

In light of teachers' stated use and appreciation for the online resources, SAE will post the Teacher Manual online as well as provide the entire manual on CD for teachers. An introductory section of the CD will highlight for teachers the sections they should plan to download and print out right away in preparation for conducting the Challenge.

Reorganize the Teacher Manual, referring back to the curriculum review conducted prior to the field test.

Based on review by an external curriculum expert that was part of GRG's evaluation, in addition to field test teachers' suggestions, SAE has modified the Teacher Manual to make it more manageable and user-friendly. The manual itself has been shortened and an appendix provided will include all of the background information and resources a teacher may need.

Make instructions, suggestions, and potential challenges with materials and implementation transparent. Include additional tips for extending the activities for older or younger students, and ideas for more cross-curricular integration.

Suggestions for activities that may be skipped or modified, as well as areas where teachers may expect to spend some extra time, are included in the appendix and highlighted briefly throughout the manual. In order not to overload the information provided for individual lessons, tips for extensions will most likely be included in the appendix only.

Emphasize and increase the training provided for this new AWIM Challenge. A visual reminder of instructions and resources, included on the Web site, would reinforce instruction from the in-person trainings.

SAE will offer extensive training options as well as encouraging teachers to work with volunteers in the classroom during implementation of the Challenge activities. Graphic artists will create photographs included throughout the manual to decrease confusion teachers may have experienced in deciphering drawings of the fuel cell operation procedures. Additionally, online resources will include multimedia flash formatted video with animation and voiceovers.

Require Design Log use for a portion of the activities. Explain the purpose and value to teachers and provide tips for teachers to convey value to students (e.g., referring to prior work helps with subsequent activities).

Trainings for use of the Fuel Cell Challenge will emphasize and highlight the value of the Design Logs and help teachers to convey to their students the importance of this tool despite their (i.e., students') distaste for paperwork.

Continue to encourage teachers to work with an industry volunteer and add tips on how to locate a partner. Add and promote opportunities for teachers to connect with one another during use of AWIM Challenges.

SAE has implemented and will continue with several initiatives to enhance the teacher-volunteer partnership for AWIM Challenges generally (e.g., AWIM workshops for teachers and volunteers, AWIM Network Groups). They will enhance efforts around helping teachers find volunteers to work with in their classrooms. Additionally, steps are in place to create a safe teacher forum to be included on the AWIM web site.

CURRICULUM EXPERT FOLLOW-UP

Upon review of the Fuel Cell Challenge, revised based on field test recommendations, the external curriculum expert perceived that SAE had effectively implemented the recommended changes. The organization format, including clearer bolded headings, was considered a major improvement, such that teachers will be better able to skim through the materials to find what they need. Additionally, the inclusion of brief Teacher and Volunteer Tips in the left margin were considered helpful and appropriate in their brevity.

Remaining suggestions included providing the standards alignment in a list or chart format rather than in the left margin, and adding interesting graphics or logos in the initial RFP to students to engage and captivate students' interest immediately.

In conclusion, the Fuel Cell Challenge has the potential for success as a stand-alone curriculum among the existing AWIM Challenges. The topic is current and exciting and the activities effectively convey the intended concepts. When teachers and students worked through their challenges and completed the Challenge, all were satisfied with the experience and their clear accomplishments.