Board 392: Support Teacher Course Development through TeachEngineering Standard

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Abstract

One of the requirements for a teacher participant in a National Science Foundation (NSF) Research Experience for Teachers (RET) site is to convert the knowledge from the research experience into K-12 course curriculum. This motivates the teacher participants to actively think about how to convert the university research knowledge into something understandable by K-12 students. Each teacher needs to play a more active role in participating and drilling down into the research to effectively create new materials, rather than as a watcher or bystander of research activities. The course development usually needs to follow some curriculum standards such as Next Generation Science Standards (NGSS) in many states and Texas Essential Knowledge and Skills (TEKS) in Texas. NGSS is too general to provide useful guidance for detailed course module development. TEKS is very detailed in each course's requirement, but teachers need to find their own ways to meet these requirements. NSF RET solicitation recommends the use of TeachEngineering.org (TE) template as the standard for course module development and distribution. Therefore, TeachEngineering template has been used by the teachers in our RET sites in the past few years. However, the acceptance rate of our teacher's submission to TeachEngineering.org is consistently low (about two out of 12 teachers in each cohort can complete), even though a $1,800 incentive course fee is offered for each successful submission. Teachers cited various reasons for not completing the submission: too busy / no time, too much trouble, cannot find a good topic, very long review cycle, miscommunication (never got emails), no clue on how to revise when the first submission was declined, etc. A teacher needs to be highly self-regulated and persistent to complete this submission process. As such, a set of interventions was taken to improve the submission success rate starting from 2022. The actions include: 1) coordinate with TeachEngineering.org about shortening the review cycle time; 2) improve communications (make sure emails are not blocked by local school districts or go into a spam folder); 3) invite the TeachEngineering director to give an introductory talk to teachers at the beginning of the RET summer program; 4) recruit an experienced master teacher to provide more detailed guidance; and 5) follow up by the professors to ensure the course module quality. As a result, the submission success rate has been improved. Six out of the 12 teachers in summer 2022 have published their TeachEngineering course modules with a few more in the pipeline. Two teachers in the summer 2023 cohort have already published their course modules. One course module excerpt is provided as an example in this paper.

1. Introduction

Texas House Bill 5 requires enhanced STEM contents in high school curriculum as part of the graduation requirement [1]. Bill 5 lists four levels of high school advanced courses for graduation: Foundation, Endorsement, Distinguished, and Performance Acknowledgements.

Each level has an increasing level of course contents in advanced STEM topics [2, 3, 4]. However, many high school teachers have not received sufficient training to prepare more advanced learning modules.

Therefore, it is imperative to strengthen the STEM teacher education and build long-term partnerships between high schools and universities to stimulate high school students' interest in STEM. To this end, the National Science Foundation (NSF) funds 8~10 Research Experience for Teachers (RET) sites in engineering education each year. Each RET site hosts 8~12 teachers for at least six weeks in the summer in a university. In the research activities, teachers are mentored by university professors and supported by the research assistants.

For RET teachers, they are expected to participate in the lab research and create instructional materials based on their research experience. While other RET sites may have different plans for the course module development, one common criterion as recommended by the RET solicitation is to submit the course modules to TeachEngineering.org. TeachEngineering is a free digital library of K-12 engineering learning materials. We have received RET grants twice, first at Lamar University and then at University of Houston. Both are designed for high school teachers to participate in the advanced design and manufacturing research. In both sites, each teacher is required to create one course module that is accepted for publication by TeachEngineering. As an incentive, the teacher is awarded the $1,800 course fee upon the acceptance of the course module.

However, not every RET teacher can successfully complete and submit the course module development. In addition, the acceptance rate of TeachEngineering course modules developed by the teachers are low. Therefore, our research team decided to intervene and provide more support to improve the acceptance rate. This paper documents our effort.

The rest of the paper is organized as follows. Section 2 discusses the intervention to improve course module acceptance rate. Section 3 discusses the TeachEngineering template. Section 4 showcases one course module example recently published by our RET teachers. Section 5 has the conclusion for the paper.

2. Intervention to Improve Acceptance Rate of the Course Modules to TeachEngineering

Through the discussion with RET teachers, they cited various reasons for not completing the course module submission:

1) They are too busy and have no time for extra work. High school teachers need to teach courses pretty much for the whole days. They are either teaching in the classroom or preparing for the courses. After full days of work, they often do not feel like doing additional work to develop course modules. Without proper guidance, they feel this is a great amount of work to develop, implement, evaluate, and submit.
2) Some teachers feel that there is a disconnect between their summer research topics and their courses in high schools. Teachers are matched to the research mentors based

on their background and interest as much as possible. However, it is highly possible that teachers teach a different subject in the following academic year. In fact, many teachers do not know what they need to teach until a few days before the semester starts.

3) Some teachers manage to complete the course module and submit it. After submission, it will be reviewed by TeachEngineering for contents and compliance with the format requirement. Most of these modules will be returned for revision, similar to a journal paper review process. For some reason, sometimes this review process is very long. By the time that the teachers received the feedback, they have forgotten what they have developed and lost the momentum. Some teachers reached out to TeachEngineering while waiting for review or during revisions, but did not receive timely responses and then lost track. The long review cycle time, while common for academic papers, wears out some teachers. Upon checking with TeachEngineering staff later, it was discovered that some ISD email addresses blocked the emails from TeachEngineering or automatically diverted them into the spam folders.
4) One of the biggest hurdles in preparing the activity and/or lesson is the lack of information on how and where to start. The teacher participants have very vague ideas of what the activity or the modules should look like. Guidance like showing them actual work by previous teachers may help a lot since they now have a guide and can see how doable the activities and modules are.
5) The old TeachEngineering template was longer and required a lot more details to provide than the newest template. Some teachers found it tedious to complete the template.

From the discussion with teachers, it is obvious that a teacher will need to be highly self-regulated and persistent to complete this submission process. As such, a set of actions were taken to improve the course module acceptance rate starting from 2022. These actions include:

1) Coordinate with TeachEngineering.org about shortening the review cycle time. During the NSF EEC (Education and Engineering Centers) Conference 2022, the author met the TeachEngineering (TE) staff and expressed the concerns about the review cycle. The TE staff promised expedited review in the future to provide better user experience.

2) Improve communications. During the discussion with the TE staff, it was found out some emails are blocked by local school districts or go into a spam folder. As a result, some teachers questioned why TE was not interested in their submitted course modules, while on the other hand, TE editors wondered why there was no response from the teachers. To work around this problem, teachers are now advised to use at least two email addresses: one from school and a personal email address such as Gmail.

3) Invite the TeachEngineering director to give an introductory talk to teachers at the beginning of RET summer program. This is a service provided by the TE staff, but it is not well utilized by the RET programs. At the start of summer 2023, we invited the TE staff to provide a

one-hour webinar to our teachers, followed by experience sharing by the teachers who had successful submission experience.

4) Recruit an experienced master teacher to provide more detailed guidance. There are some teachers with rich RET experience. In fact, many teachers with RET experience are looking for new RET opportunities. With their experience, they can provide guidance to other teachers on almost everything: research, teaching, and module development. For each cohort, we recruit one such master teacher to organize meetings and guide other teachers. We were fortunate to recruit a high-quality master teacher each summer to assist teachers. This is especially true in the past two summers when our master teacher provided a lot of guidance in completing the TE course module development, submission, and revision process. One on one meetings with the teachers were completed to address each teachers' doubts, needs, questions. Guidance was provided in creating the activities based on the lab and the lessons that the teachers teach in their high schools. The master teacher also provided the RET participants a sample of submitted modules that have already been approved and showed them the complete process of approval. This gave the teachers more confidence in preparing their modules.

5) Follow-up by the professors to ensure the course module quality. The follow-up by the research mentors is very important to ensure the course quality. Our research mentors need to visit the high school to see the course module implementation and provide feedback. When we visit the classroom, we see how the course module is implemented in the classroom. We also review the course module before/after the module implementation. Based on that, the course module is modified and submitted to TeachEngineering.org.

3. TeachEngineering Template and Feedback

The TeachEngineering website provides the six-step procedure for submitting the course modules [5]. There are two important forms: pitch template and activity template.

3.1 Hands-on Activity Pitch

TeachEngineering invites teachers to propose an original, hands-on activity, starting with the pitch form. The pitch allows a teacher to prepare a short proposal to briefly explain the course module idea. The pitch can be reviewed quickly by the TeachEngineering staff. This ensures that the teacher receives feedback in the early development stage and will be pointed to the right direction down the road of module development. The pitch form template can be downloaded and includes the following sections:

1) Contact information
2) Topic
    a. What grade does the activity serve?
    b. What topic is covered?
3) Activity details: title, summary, and outline of hands-on activity

In the summer 2023, most RET teachers completed the pitch forms and got them approved. It is to be noted that these submissions and approvals were done before the summer session ended. This is an important factor since the momentum of the teachers to pursue and submit the activities is still high and the master teacher's guidance is more accessible.

3.2 Hands-on Activity Template

After the pitch is approved, the teacher can then go ahead to complete the course module development. The teacher can download the hands-on activity template form and fill the course module details [6]. The template has five parts:

1) Overview: title, grade, time, group size, summary, testing (evaluation), education standards, learning objectives, and prerequisite knowledge. In the education standards, a teacher is expected to connect with Next Generation Science Standards (NGSS), which is used in many states but not in Texas. The corresponding standard in Texas is Texas Essential Knowledge and Skills (TEKS). For the teachers in our RET sites, they are developing their course modules by following TEKS which is very detailed in course requirements. When submitting the course modules, teachers need to find the matching NGSS items for national distribution.
2) Instructional Plan: equipment and materials, introduction, procedure, assessment (pre-activity, formative, and summative), worksheets and attachments. This section describes the most important contents of the course module.
3) Supporting activity information: scaling, extensions, and enrichment.
4) Contributor, Supporting Program, and Acknowledgements.
5) Photos and Images.

3.3 Hands-on Activity Review and Feedback

After the activity is submitted, it is sent to external reviewers for review, similar to a journal publication process. After the reviewers submit the report, the TeachEngineering editor will provide editorial comments along with the individual review reports to the author. Sometimes, there may be multiple revision cycles. This is a rigorous process that some teachers find hard to deal with, especially over a period of several months.

After authors submit their curricular item to the TE online journal system, their submission is first reviewed by a TE editor or TE project engineer for hands-on components, classroom testing, connection to engineering, and completeness, using a submission rubric developed by the TE editorial team. Many authors who submit to TE do not realize that TE is engineering-design focused and/or requires all activities be hands-on (e.g., measuring, building, creating, or testing something). It is during this initial review stage that submissions may be (a) returned to authors for further details, changes, and/or edits, (b) accepted for external review, or (c) rejected for not fitting the TE submission requirements. If a submission is returned to the author for details, changes and/or edits, the author may resubmit to the TE editorial team at their leisure.

Once a submission is accepted for external review it is sent out to external volunteer reviewers who are engineers or educators. The TE editor strives to get at least two external reviews for each submission (one K-12 educator and one engineer). Once external reviews are conducted, the TE editor reviews all reviewer feedback and then individually reviews the submission. The TE editor then contacts the author with the reviewer feedback, or in the very rare case, lets the author know that TE cannot accept their submission. Generally, reviewer feedback is focused on (a) how the activity relates to engineering, (b) if the engineering or science taught in the curriculum is correct, and (c) whether the activity (as written) is appropriate for a K-12 teacher to teach it. After receiving external feedback, authors are given as much time as they need to complete the revisions, generally they take ~ 2-12 months. Upon receiving an updated and revised submission from the author, the TE editor checks the revisions for accuracy and completeness, sending it back to the author if further work is needed.

In the *initial review stage*, the most common teacher-author mistakes are:

a. not filling out the TE activity template completely
b. not having a hands-on activity (i.e. lacking engineering design)
c. materials required are too costly
d. missing classroom testing information
e. missing images (TE requires a minimum of two original photos per activity to help teachers visualize the nature of the activity.)

In the *external reviewer stage*, the most common mistakes teacher-authors make include:

a. not providing enough details in the procedure of the activity for future users (e.g., educators) to replicate the activity
b. not connecting their submitted activity to engineering
c. not recognizing and/or calling out the various engineering design steps in their procedure
d. not providing sufficient background information on the activity topic for the future users (e.g., educators).
e. not providing complete assessment (i.e., missing answer keys/ sample answers)
f. missing attachments and/or not in editable format.

4. An TeachEngineering Course Module Examples by Our RET Teacher

A high school teacher participated in a summer project that involves hydrogels. Inspired by the research, the teacher developed a course module to teach biodegradable materials. The course module, titled "Hold On to That Water! Making Biodegradable Hydrogels" , covers 11 days of activities with an engineering design focus. The following is an excerpt from the course module provided by one of the co-authors [7].

Summary

What can engineers do to help solve problems related to water conservation? In this activity, students design methods that concentrate on supplying plants with a steady source of water without the cost or depletion of aquifers caused by using some type of irrigation method. Students develop hydrogels that help to retain soil moisture while being biodegradable and nontoxic. *This engineering curriculum aligns to Next Generation Science Standards (NGSS).*

Learning Objectives

After this activity, students should be able to:

- Describe the ways the proposed solution decreases the negative effects of human activity on the environment.
- Calculate the amount of water released and reabsorbed by the individual hydrogel formulations.
- Determine which hydrogel formula would be the best solution to retain soil moisture with appropriate reasoning.

Procedure

Background

Conservation of water is a worldwide issue that concerns everyone. Even areas that have seemingly large water reserves, such as the Great Lakes, still have areas with water shortages. There is a huge variety of ways to conserve water or protect water resources but there are also many competing entities using those resources. Clean water is needed for drinking, household use, laundry (including hotels and other commercial businesses), agriculture, recreation, and wildlife. This activity focuses on conserving water used for agricultural purposes. An extension of this activity using fertilizer built into the hydrogels can also help to reduce runoff into rivers and lakes that cause pollution.

The making of the hydrogels is simple, very similar to making Jell-O. The CMC, agar, and / or HEC powders provide the polymers that make a network to hold the water and give it structure. A slightly acidic solution seems to promote those polymers to arrange in a way that allows the water molecules to enter or leave the structure more easily. This is the reason the citric acid powder is used.

This is a good activity to explore the engineering process since there are very few needed components and there are also a variety of ways to extend the activity. Students can explore which of the polymer powders, or combination, works better. The hydrogels perform best when using a combination of two of the polymers. Furthermore, they can make hydrogels with varying amounts of polymer powder to which one reabsorbs the most water. Hydrogels that are very firm, which contain many polymers, do not reabsorb very much water. Students may even propose a new polymer to try such as gelatin. These do not work as well, but it would add more data to the engineering and scientific process.

All energy used by most organisms on earth ultimately comes from the sun and is transformed by plants through the process of photosynthesis. The glucose produced forms the basis of the food

chain for a vast array of other organisms. The optimum productivity of plants is essential for providing enough food for the multitude of other organisms. The necessary reactants for photosynthesis, in addition to sunlight, are carbon dioxide and water. There is an overabundance of carbon dioxide on earth, but water is not always readily available. This activity concentrates on suppling plants with a steady source of water without the cost or depletion of aquafers caused by using some type of irrigation method. Students will develop hydrogels that help to retain soil moisture while being biodegradable and nontoxic. This activity can easily be adapted to be a short lab activity or extended into a long-term project.

The first part of the lab will determine what component(s) will dehydrate and then reabsorb the highest percentage of water. There are 3 components that are available: agar, hydroxyethyl cellulose and carboxymethyl cellulose. The citric acid is used in all combinations to make the solution acidic which helps the hydrogel polymers to build a strong network. The students can choose the combination they want to test or the teacher can assign the combinations. There are 6 prepared combinations, but you can have groups test more or do repeat testing.

After data from the first round of testing is complete, the class will continue testing to further improvement the hydrogel product. The refinement of the hydrogel is a continuation of the engineering process. Typically, testing on a product will continue beyond the first round of tests to help improve the product or to determine if it fully meets the parameters set forth. Note, the first round of testing can be eliminated for time or money constraints, and you can go directly to the second set of experiments.

Figure 1. Initial trials of varying polymer ratios.

The 11 days' activities are described after this.

Assessment

Pre-Activity Assessment

Whole-class Discussion: The pre-activity assessment is the content of the discussion during the engage portion of the activity. Students should be able to describe ways the proposed solution decreases the negative effects of human activity on the environment.

Activity Embedded (Formative) Assessment

Presentation of Data: The formative assessment for this activity is the presentation of data, claim, evidence and reasoning on whiteboards during a whole class discussion.

Post-Activity (Summative) Assessment

Lab Report: The summative assessment is the written lab report.

5. Conclusion

Through the intervention and support documented in this paper, the two cohorts of summer 2022 and 2023 have higher success rates compared to the first cohort in summer 2021.

Only two teachers from summer 2021 completed the course module submission process. Six out of the 12 teachers in summer 2022 have published their TeachEngineering course modules with a few more in the pipeline. Two teachers in the summer 2023 cohort have already published their course modules. While the teachers are responsible for developing course modules, the support from master teachers, research mentors, and TeachEngineering staff, etc. are all critical to the completion of the whole submission process. In the future teacher-related summer research, we will continue to execute the intervention strategies outlined in this paper to ensure high quality course modules and high completion rate with TeachEngineering.

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