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Faculty and Student Perceptions on Shared Teaching Materials for Advanced Manufacturing (STAM): Building Momentum Through Workshops

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Abstract

In this paper, we summarize the outcomes of the two workshops aimed at speeding up the transition of research-based advanced manufacturing knowledge into course curriculum for technology and engineering programs. Advanced manufacturing technologies have opened up the realm for new products that only a decade ago were considered unproducible. For example metals 3D Printing has almost no geometric limitations, which allows engineers to develop mesh–based products. Unfortunately, the educational system that serves to educate the majority of manufacturing technicians and engineers still utilizes many of the same curriculum resources for these emerging areas (textbooks, traditional lectures, etc.), frequently creating an unsuitable or inappropriate learning environment for state-of-the-science technician and engineering training. This is especially true for the development of manufacturing materials and laboratories to maintain currency in advanced manufacturing. With funding from NSF, two workshops were conducted that generated great enthusiasm for the concept of a teaching repository for advanced manufacturing technology. More than 50 advanced manufacturing instructors have attended the workshops, and a community of instructors has been created. Results from faculty and student perceptions on shared teaching materials for advanced manufacturing are also shared.

1. Background

Technology is developing at a more rapid pace than ever before, yet we believe the methods used to teach technology have not advanced at the same pace. Engineering and technology instructors are required to keep pace with the advancing technologies, but it seems that their teaching loads have grown at a time where just keeping pace with evolving technology is more difficult than ever. It is our opinion that at the four-year university settings, most instructors utilize their research to keep pace with technology advances. Engineering instructors also leverage their research to create textbooks in evolving areas so that they can bring new technologies into the classroom reasonably quickly, and in fact, this is one of the expectations in typical promotion and tenure (P&T) considerations (See Figure 1 for examples). We assert that the engineering education system is at a disadvantage in this arena due to heavy teaching and research loads which make it difficult to spin new courses and areas of study.

Informed by these observations, this paper focuses on a new approach to develop teaching technology-based materials so that rapid course development can be achieved more quickly and inexpensively for students in engineering and technology programs. Although needs are much broader, we limit our domain of focus to manufacturing, an area that we feel is critical for our nation's economy.

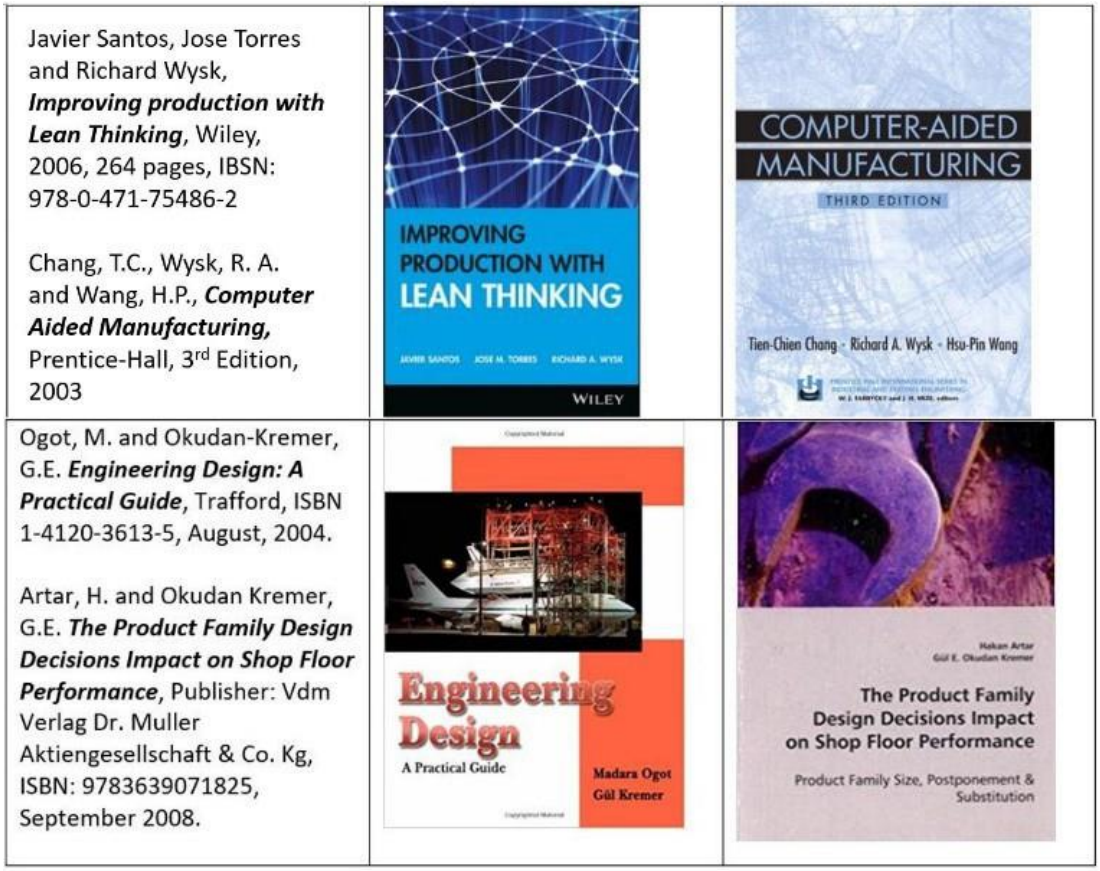


Figure 1 Textbooks are informed by faculty research

As engineering faculty our experiences have led to an interesting observation where they see that researchers have created a "highly organic" set of materials in the form of technical papers and research reports that get rapidly shared with other researchers at conferences and research-focused events. Although the ideas behind the developments are protected by patents and invention disclosures, there is a constant focus on getting new ideas out before someone else gets credit for them. Textbooks are a different story in that book authors receive revenues for their efforts, and "protect" their investments. However, this protection cannot come before properly educating our engineers. We feel that if textbook materials can be made available for instructors at all levels to use and modify as they see fit; the result will be that the content and quality of these materials will increase at a much more rapid pace. By developing a community of instructors who collaborate using these materials, we feel that the materials will continue to grow and improve making them "organic".

Publishers have had "custom textbooks" for a couple of decades, but the results have not been very positive. Many technical texts have many topics that go uncovered in courses, but still find their way into the textbook. Teachers create examples to supplement the text, but do not share these examples with the rest of the academic community. Laboratory experiments are frequently developed for specific courses that reinforce learning concepts, but are not shared with others except through informal exchanges. This is one of the gaps that we address in this effort. Overall, what we observe currently and what we envision can be summarized as follows:

A Typical Advanced Manufacturing Course Current Textbook Situation:

- Engineering and science texts are expensive and contain a large volume of material that will not be used during the course. Many faculty attempt to "crossover" textbook usage to subsequent courses, but students who do not enroll in those courses (or do not persist) do not enjoy the return on investment, e.g., Fundamentals of Modern Manufacturing: Materials, Processes and Systems, 5th Edition $212.95; Manufacturing Engineering& Technology, 7th Edition $219.80.
- Large volumes of print materials are compiled by the author, most of which goes unread.
- Authors sometimes opt for quantity rather than quality, adding material to their publications which does not add value to course content.
- The one-size-fits-all textbook where all material, regardless of laboratory supplements,gets used. Machines that will be used in the lab may not be in the book.
- Several books are available in paper format only, a truly troublesome issue from a sustainability and waste perspective. PDF versions are available, but seem to serve to only reduce print costs without addressing other quality issues.

Our vision for Shared Teaching materials for Advanced Manufacturing (STAM) courses:

- Engineering and science texts/chapter materials will be available on the web with accessto project members, and will contain relevant materials specified by the course instructorfor STAM course(s).
- The STAM project development team and community will compile new chapter materials (or electronically "paste" them together) into customized chapter modules (book-like addition) for a particular course.
- Materials from various authors will be organized into topic chapters with homework problems and assignments especially focused on a particular course and laboratory hardware and demonstration materials.
- The repository will provide indexed topic materials (chapters, problems, quizzes, tests, exercises, etc.) in pdf form so that they are searchable, accessible, and available for a broad set of media.
- Presentation materials/slides for the topics will also be made available on the web.
- Presentations for some of the materials will be available for asynchronous teaching or "flipped" instruction.
- Materials can be tailored to the educational level, backgrounds, and learning styles of students and to the equipment available in laboratories.
- Faculty may "check out" materials to repurpose them, adding perspective, activities, and assessments that they have found to be current and relevant. Faculty should then "check in" the adapted materials for others to use and repurpose themselves.
- Materials will eventually be developed to be accessible to students and faculty with impairments (i.e., all content will be screen reader friendly; when possible podcasts will be added as course content).
- The customized textbook will be available in file formats (e.g., pdf) accessible by a broad set of contemporary media (e.g. PC, iPad, Kindle etc.).

In an effort to establish the viability of STAM and gage the interested from the community, two workshops were held, and faculty and student surveys were conducted. Below wesummarize these in two sections.

2. Community Building Through Workshops

To identify roadblocks and hurdles associated with the vision for STAM, and lay the groundwork to develop an Advanced Manufacturing Education Community of instructors two workshops were organized. Lists of people involved in advanced manufacturing teaching were generated from Society of Manufacturing Engineering (SME) accreditation materials, Institute of Industrial and Systems Engineers (IISE) materials and mechanical engineering materials. These lists were used to invite perspective workshop attendees to each of the workshops. Most of the invitees have titles such as Product Engineers, Manufacturing Engineers and Manufacturing Technologists and Industrial Engineers, and were teaching faculty at educational institutions across the U.S. The workshops were intended to both: 1) Identify a comprehensive set of problems associated with our "organic materials" concept, and 2) Obtain buy-in for the concept so that a community of educational innovators can be developed.

Table 1 List of workshops, dates and locations

Workshop No.	Date	Location	Event	No. Attendees
1	May 25, 2019	Orlando, FL	IISE Annual Conference	21
2	September 17, 2019	Raleigh, NC		29

Workshop materials were developed and are shown in https://manufacturingeducation.wordpress.ncsu.edu/stam/. From the materials, one can see that the presentation materials were developed with a focus on the instructors involved in teaching advanced manufacturing topics. The workshops were designed to expose this concept to people teaching in the advanced manufacturing arena in order to get their feedback on potential problems and requirements to make the transition to the "Advanced Manufacturing Teaching Repository" for the courses that they teach.

The first workshop generated significant enthusiasm for the STAM Repository concept. A list of Roadblocks and Incentives are provided in Tables 2 and 3.

Table 2. Roadblocks identified

Roadblock	**Description**	**Specifics**
Classifying Topics	Developing a taxonomy for materials so that materials will be easily searchable	Create a reasonably complete taxonomy
Editing proofing	Updating materials as they are returned with modifications	How do we get people to proof other's work?
Intellectual property	Who owns changes made to existing materials?	How do author(s) get credit for their work?
Sustainability	Who will support the management of the repository?	Storage and management of materials is not free but should be far less than for a traditional course.
Security and management of the repository	Where will the repository be located? Who will provide security for the system?	Make sure that students do not access test information and sensitive, but instructors do.
Faculty buy-in	Will instructors use and be receptive to a repository?	Develop a survey and administer it to teaching instructors.
Community development	Will manufacturing instructors commit to developing and using arepository?	

Table 3. Incentives for repository

Characteristic	**Description**	**Specifics**
Money saving for students	Developing a taxonomy for materials so that materials will be easily searchable	Text materials can be assembled for specific courses without textbook charges.
Time saving for instructors	Updating materials as they are returned with modifications	Chapters, notes, tests and problems will be available for instructors
Standardize testing for topics	Develop a catalogue of test problems and questions that can be used	Large and statistically significant data will be identified.
Flexibility	Regional topics can be easily included in course materials. New topics and technologies can be rapidly introduced.	Courses can be customized by manufacturing process or products.
Faculty interactions	The teaching community will be able to communicate potential difficulties and solutions.	

Takeaways from workshop #2 are summarized in Tables 4 and 5

Table 4. Roadblocks identified

Roadblock	Description	Specifics
Student input is needed	A survey should be developed to get student opinions concerning a repository	Determine acceptable an unacceptable media and methods for using a repository
Create and executes survey	What do we need to ask students?	
Create an awareness of STAM	Make the teaching community more aware of STAM	Develop a presentation for Engineering Conferences
Need to get legal counsel	Need to define use terms for using a repository	

Table 5. Incentives for repository

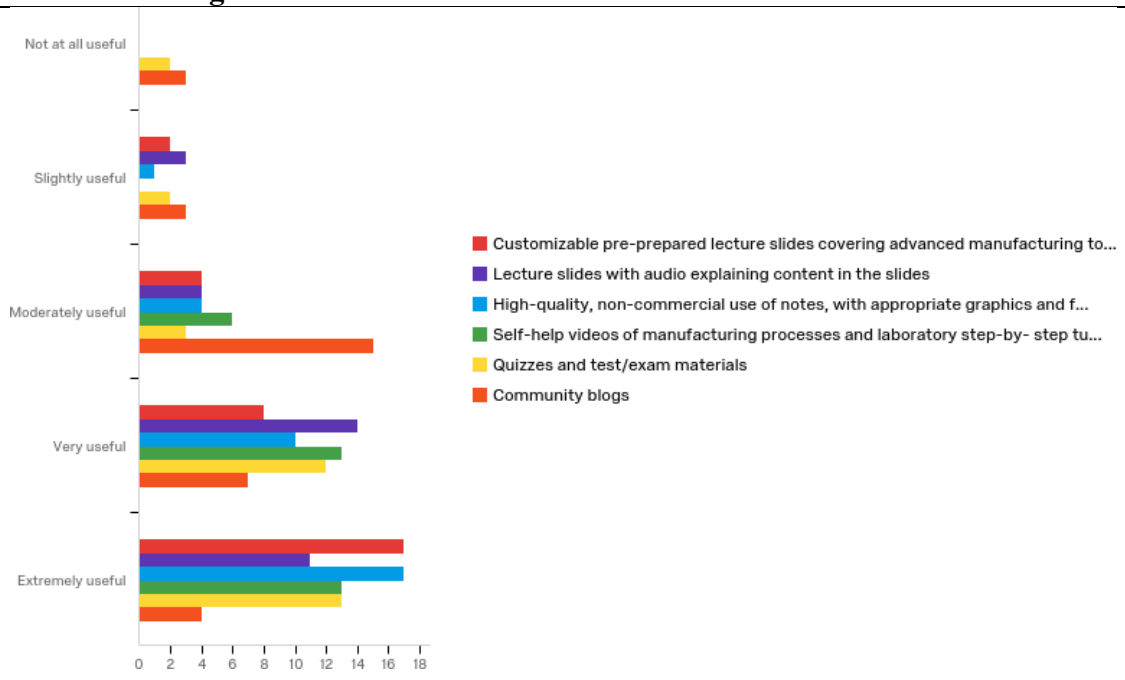
Characteristic	Description	Specifics
Develop a STAM Website	Developing a with materials so that STAM can be realized	Alpha Website is in place.

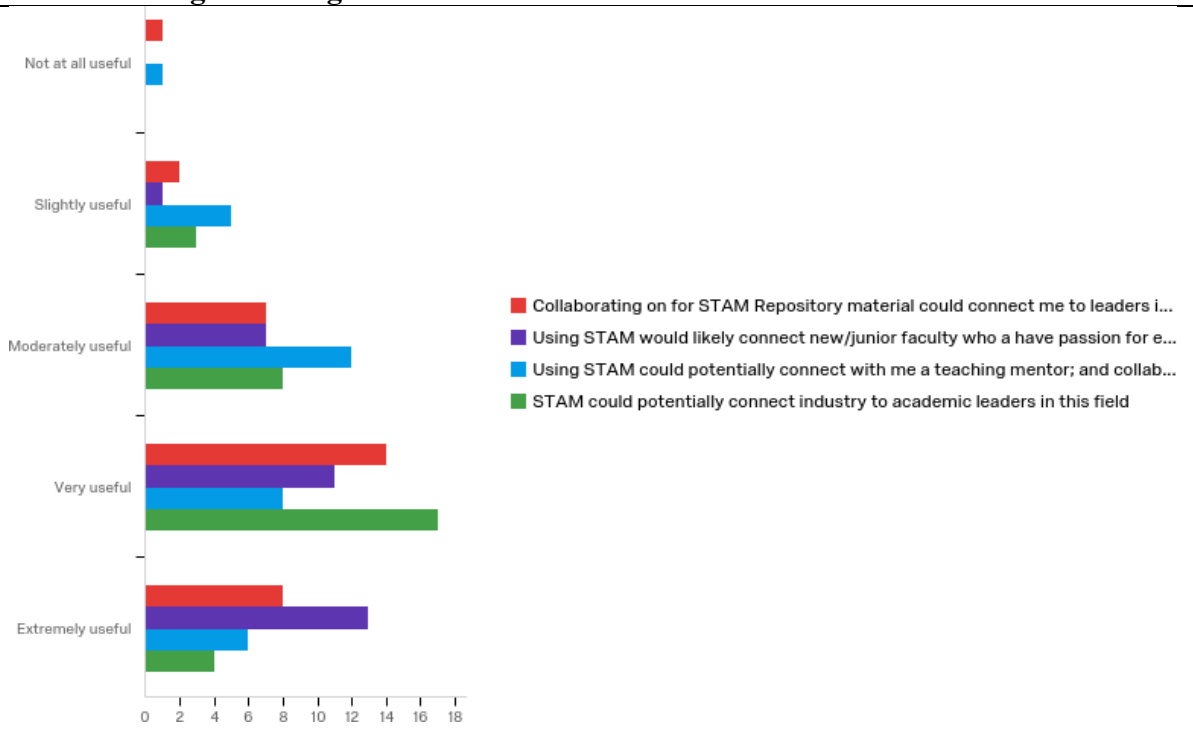
3. Faculty and Student Survey Results

Two surveys were developed and executed between October 2019 and March 2020. A select set of survey results are summarized below, and student survey questions are provided inthe Appendix. It should be noted that many of the questions in Survey #1 and Survey #2 were similar in nature, but Survey #1 was intended to get "faculty" opinions while Survey #2 was intended to get "student" feedback. Overall, we observe continued enthusiasm for the development and use of the STAM Repository. It appears that students have a more modern focusto use electronic copies over traditional paper based materials, but the use of the repository is strong.

In the faculty survey, initial sections collected information about the respondents (teaching experience, rank, etc.), their institution (type, etc.), and textbooks they are currently using manufacturing courses. They were then provided an opportunity to describe the manufacturing courses in their program considering the laboratory experiences (no laboratory experience for students, some laboratory experience, and extensive laboratory experience).

C2	**The time currently required to develop course materials for advanced manufacturing instruction is:**
	Much higher than a typical engineering course 22.58% Somewhat higher than a typical engineering course 67.74% About the same as any engineering course 9.68%

C3	**If a repository of existing materials (lecture slides, self-help videos, reading materials), for advanced manufacturing was available for university instructors to utilize, the time required for course preparation would be:**
	Significantly reduced 56.25% Somewhat reduced 34.38% Remain about the same 6.25% Somewhat increased 0.00% Significantly increased 3.13%
C4	**If a repository of existing materials for advanced manufacturing was available for university instructors to utilize, the quality and content of the course would be:**
	Significantly improved 62.50% Somewhat improved 34.38% Remain about the same 3.13% Somewhat increased 0.00% Significantly increased 0.00%
C5	**Would you be willing to contribute learning material to the STAM Repository?**
	No, I am firmly against openly sharing lecture material with the community 0.00% Yes, I would not mind contributing content to the STAM Repository 96.77% I would be involved in the development and use of the STAM Repository, but I will not contribute my materials 3.23%
C7	**Rate the usefulness of each STAM Repository component to course instruction and student learning:**
	

C8	**Rate the usefulness of the STAM Repository in facilitating connections to manufacturing and design educators.**
	

Given the above table of responses to the select faculty survey questions, it is clear that faculty do see value in various STAM components, and they would like to contribute to it, and use it.

A total of 179 students responded to the Student Survey. Most of these students were at junior (34.64%) and sophomore (43.58%) standing. Most of the student respondents were from large university settings (more than 8000 students in their Engineering College). As it can be followed in the select question summaries below, student reactions to the envisioned repository is also very positive.

Q 6	**What percent of the book do you currently use?**
	More than 75% 1.67% Between 50% and 75% 12.22% Less than 50% 86.11%
Q 8	**The course that I have taken (or am currently taking) has:**
	No laboratory experience for students 1.11% Some laboratory experience for students 35.56% Extensive laboratory experience for students 63.33%
Q10	**If a repository of existing materials for advanced manufacturing was available for university instructors to utilize, it would:**
Equivalent to C 4	Significantly improved 29.44% Somewhat improved 51.67% Remain about the same 17.22% Somewhat increased 1.67%

	Significantly increased 0.00%

Q 14	**Students enrolled in a course that utilizes a repository, will likely:**
	Have far better/easier access to timely materials 39.78%Have little better/easier access to timely materials 43.65% Have the same access to materials 14.92% Have a little worse access to materials 1.66% Have far worse access to materials 0.00%
Q 18	**Students enrolled in a course that utilizes a repository, will likely:**
	Have a far better experience in taking a course due to timely materials and shared exams and quizzes (35.91%) Have a somewhat better experience in taking a course due to timely materials and shared exams and quizzes (46.96%) Have about the same experience as participating in a traditional course (14.92%) Have a somewhat worse experience in taking a course using the repository (2.21%)

4. Conclusions

The STAM concept was viewed very favorably by both students and faculty involved with advanced manufacturing technology (AMT). Students and faculty felt that the cost of offering or taking an AMT course could be reduced as expensive engineering texts would be replaced with chapter materials from the STAM repository, and development time to customize a course for a specific university would be shortened. The time required to customize educational materials to better fit regional industry needs would also be shortened. Students liked the idea of having their course materials being made available on a variety of media (print, video, web, etc.) as it better fit their learning and time preferences. Course instructors also felt that tests, quizzes, projects and laboratory exercises would be improved by using previous used ones as a starting basis for developing new ones. One of the most highly expected results for STAM is that laboratory exercises could be shared remotely with institutions that did not have the necessary demonstration hardware to run in-person laboratory exercises.

Some unresolved issues associated with STAM were also noted. For instance, access securitymust be in place, and faculty "owned material" needed to be kept from students. There was alsoa concern expressed for how instructors would receive recognition for developing new text materials and examination methods. The entire issue of *intellectual property ownership* wasconsidered an issue that could affect the participation of some faculty.

The potential benefits from a STAM repository appeared to outweigh the difficulties associated with developing it. The community of AMT instructors seem very excited about the possibilities for a STAM. It will make the education of AMT courses better and more economical.

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Disclosure statement

No potential conflict of interest was reported by the authors

Appendix 1. AMT Instructors' Survey
Default Question Block

This survey is intended to gather opinions concerning the use of shared teaching materials for advanced manufacturing processes related courses. You may know that we received an award from the National Science Foundation (NSF) to conduct three workshops to investigate “Shared Teaching Materials for Advanced Manufacturing” (STAM). The first workshop was conducted in conjunction with the IISE annual meeting in Orlando, Florida on May 18, 2019. The purpose of the workshops was to gather ideas and plan a larger proposal to NSF to support this concept of creating a repository for manufacturing teaching materials. The repository would hold print modules/text chapters, presentation slides, laboratory exercises, quizzes, tests, homework, and video presentations related to a variety of manufacturing topics.

We feel that a focused technical community of college educators can share their experiences and materials so that a broad compilation of educational materials can be provided to participating schools that will catalyze and advance the development of this important topic/area. We also feel that this repository will serve as the seed for an “organic set of teaching materials”, which will continue to grow over time.

This survey represents some general categories associated with developing such a repository, and is focused on trying to overcome some of the obstacles associated with the funding and operation of such an entity. The survey is divided into three major categories: 1) Utility, 2) Necessary Tools and Technology, and 3) Sustainability. This “organic set of teaching materials” will continue to grow as a focused technical community of college educators share their technical experiences, materials and teaching experiences so a broad compilation of educational materials can be provided to participating schools. This will catalyze advances in both the teaching and the technology for modern manufacturing.

Name of Institution

Rank

- ○ Adjunct Instructor
- ○ Assistant Professor
- ○ Associate Professor
- ○ Professor
- ○ Department Head

Full Name (optional)

Name of Department

Name of manufacturing course(s) taught

Text used in the course(s)

About You and Your University

Which best describes your college or university?

- Community College
- Research 1 University
- Non-research 1 University
- Other

Which best describes your department?

- Industrial engineering
- Mechanical engineering
- Manufacturing engineering
- Other

Which best describes your teaching experience?

- 0-10 years
- 10-15 years
- 15-20 years
- > 20 years

I/We currently use the following book to teach manufacturing processes:

- Groover
- Degarmo, Black, Kosher
- Kalpakjian
- Other

Our program has

- no laboratory experience for students
- some laboratory experience for students (Please provide a url if available)
- extensive laboratory experience for students (Please provide a url if available for the lab)

Utility for a Technical Repository

Instructor Point-of-View

The time currently required to develop course materials for advanced manufacturing instruction is

- ○ much higher than for a typical engineering course
- ○ somewhat higher than a typical engineering course
- ○ about the same as any engineering course
- ○ somewhat less than a typical engineering course
- ○ much less than a typical engineering course

If a repository of existing materials (lecture slides, self-help videos, reading materials), for advanced manufacturing was available for university instructors to utilize, the **time required for course preparation** would be

- ○ significantly reduced
- ○ somewhat reduced
- ○ remain about the same
- ○ somewhat increased
- ○ significantly increased

If a repository of existing materials for advanced manufacturing was available for university instructors to utilize, the **quality and content** of the course would be

- ○ significantly improved
- ○ somewhat improved
- ○ remain about the same
- ○ somewhat decreased
- ○ significantly decreased

Would you be willing to contribute learning material to the STAM Repository?

- ○ No, I am firmly against openly sharing lecture material with the community.
- ○ Yes, I would not mind contributing content to the STAM Repository.
- ○ I would be involved in the development and use of the STAM Repository, but I will not contribute my materials.

If a repository of existing materials for advanced manufacturing was available for university instructors to utilize, **the breadth of the materials covered** in the course would be

- ○ significantly increased
- ○ somewhat increased
- ○ neither increased or decreased
- ○ somewhat decreased
- ○ significantly decreased

Rate the usefulness of each STAM Repository component to course instruction and student learning.

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Customizable pre-prepared lecture slides covering advanced manufacturing topics	○	○	○	○	○
Lecture slides with audio explaining content in the slides	○	○	○	○	○
High-quality, non-commercial use of notes, with appropriate graphics and figures	○	○	○	○	○
Self-help videos of manufacturing processes and laboratory step-by-step tutorials	○	○	○	○	○

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Quizzes and test/exam materials	○	○	○	○	○
Community blogs	○	○	○	○	○

Rate the usefulness of the STAM Repository in facilitating connections to manufacturing and design educators.

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Collaborating on for STAM Repository material could connect me to leaders in the field	○	○	○	○	○
Using STAM would likely connect new/junior faculty who a have passion for education in this domain	○	○	○	○	○
Using STAM could potentially connect with me a teaching mentor; and collaborative content creation can provide a mentoring opportunity	○	○	○	○	○
STAM could potentially connect industry to academic leaders in this field	○	○	○	○	○

List up to three (3) utility/quality outcomes that could affect faculty course preparation and offering not listed above but important for the use of a course repository.

☐ 1

☐ 2

☐ 3

Student Point-of-View

Students enrolled in a course that utilizes a repository, will likely

- ○ have far better/easier access to timely materials
- ○ have a somewhat better/easier access to timely materials
- ○ have the same access to materials
- ○ have a little worse access to timely materials
- ○ have far worse access to timely materials

Because of frequent updates to a repository, students enrolled in a course that utilizes a repository, will likely

- ○ be exposed to far more current and timely materials
- ○ be exposed to somewhat more current and timely materials
- ○ have the same access to timely materials
- ○ have a somewhat diminished set of current and timely materials
- ○ have far more diminished set of current and timely materials

List up to three (3) utility/quality outcomes that could affect students taking a repository-based course not listed above but important for the use of a community accessible course repository.

- ☐ 1
- ☐ 2
- ☐ 3

Tools/Technology

Using a web-based repository to prepare an advanced manufacturing course will

- ○ present more difficulties for monitoring and controlling a course teaching site

- ○ be about the same difficulty for monitoring and controlling as for any other course
- ○ reduce difficulties for monitoring and controlling a course teaching site

The STAM Repository should be

- ○ developed and maintained by a professional "for-profit" publishing company
- ○ developed and maintained by a nonprofit company/organization
- ○ developed and maintained by a professional society, e.g., IISE, SME, and ASME
- ○ developed and maintained by a university IT staff
- ○ developed and maintained by a community of national and international Instructors
- ○ other

The STAM Repository should be open to (choose as many as appropriate)

- ☐ all students
- ☐ students registered for the repository course only
- ☐ all university faculty
- ☐ only advanced manufacturing instructors
- ☐ only advanced manufacturing instructors registered for a repository course
- ☐ anyone with web access

Evaluation rubrics (homework, quizzes and tests) need to be secured, but their availability will

- ○ eliminate significant development time for tests, quizzes and homework for instructors
- ○ eliminate some development time for tests, quizzes and homework for instructors
- ○ have no effect on development time for tests , quizzes and homework
- ○ increase some development time for for tests , quizzes and homework for instructors
- ○ significantly increase development time for tests , quizzes and homework for instructors

The security for a repository system used by administrators, instructors and students will be

- ○ impossible to maintain
- ○ difficult to maintain
- ○ no different to maintain than the current system
- ○ easy to maintain

List up to three (3) technology/tools issues that could affect utilizing a Repository-based course not listed above but important for the use of a Course Repository.

- ☐ 1
- ☐ 2
- ☐ 3

Sustainability

It has been predicted that the cost to students will potentially be reduced by using a repository so that a textbook can be eliminated. The time to develop course materials for the instructors will also be reduced; however, maintenance and updates for a repository will require time and expertise. The quality and consistency of repository materials will also need to be reviewed routinely so that a STAM Repository can be sustainable.

The cost associated with developing and maintaining an advanced manufacturing repository should be

- ○ funded by a foundation
- ○ self-funded by the users (students and instructors)
- ○ maintained by a professional society to do as they see fit
- ○ maintained by a nonprofit organization
- ○ maintained by a for-profit organization

Instructors developing materials for the repository should

- ○ give freely of their time to develop new materials for the repository
- ○ be paid for their work and efforts in developing new materials for the repository

- ○ be recognized for their contributions (like a citation of IP) in developing new materials for the repository

An economic model for developing and using an advanced manufacturing repository

- ○ is needed prior to any development of such a repository
- ○ is needed but cannot be created until the repository has been developed
- ○ is not particularly important because the value is obvious
- ○ is difficult to create

How likely will you or your institution be willing to pay a nominal subscription fee to help maintain the STAM Repository infrastructure?

- ○ Definitely
- ○ Most likely
- ○ Probably
- ○ Definitely not

One of the sustainability requirements for creating an “organic” repository that will renew and evolve is the constant development and renewal of new materials by instructors. Select all below all that you feel apply.

- ☐ It is not particularly important that instructors who develop materials for the repository are given credit for their contributions since teaching is part of their job
- ☐ Credit should be similar to developing a “technical paper” where a list of authorship is maintained by the repository. Use of the material will be like a citation for professional work.
- ☐ Contributors should be paid for their time and efforts associated with developing a repository. Without this component, the repository will not be sustainable.

List up to three (3) sustainability issues that will affect utilizing a repository-based course not listed above but important for the use of a course repository.

- ☐ 1
- ☐ 2

☐ 3

Students enrolled in a course that utilizes a repository, will likely

- ○ have a far better experience in taking a course due to timely materials and shared exams and quizzes
- ○ have a somewhat better experience in taking a course due to timely materials and shared exams and quizzes
- ○ have about the same experience as participating in a traditional course
- ○ have a somewhat worse experience in taking a course using the repository
- ○ have a far worse experience in taking a course using a repository

If the repository contained videos and data from lab experiments that would illustrate concepts, would you

- ○ not need or use them
- ○ welcome the opportunity to include that content as appropriate for my course

Do you wish to receive an honorarium for completing this survey?

- ○ Yes (Please fill in your mailing information below)
- ○ No

Full Name

Email

Address

Address #2

City

In which state do you currently reside?

Zip Code

In which country do you currently reside?