First Steps with Tooling U as a Support to the Mechanical Engineering Technology Flipped Classroom

Prof. Julia L. Morse, Kansas State University, Polytechnic Campus

Julia Morse is Associate Professor and Program Coordinator for Mechanical Engineering Technology at Kansas State University Polytechnic Campus. A Certified Manufacturing Engineer (CMfgE) and a Certified Enterprise Integrator (CEI), she teaches lecture and laboratory courses in the areas of computer-aided design, manufacturing and materials, and automation systems. Prof. Morse earned a B.S in Industrial Engineering from the University of Tennessee-Knoxville and an M.S. in Manufacturing Systems Engineering from Auburn University, where she also worked with Auburn Industrial Extension Service. Her work in industry includes engineering experience in quality control, industrial engineering, and design and development functions for automotive parts manufacturers in North Carolina and Germany.

Dr. Raju S. Dandu, Kansas State University, Polytechnic Campus

Dr. Raju Dandu, professor in mechanical engineering technology at Kansas State University Salina, specializing in sustainable product design, development, manufacturing, energy efficiency, and effective equipment maintenance programs. He provided reliability centered maintenance instruction and hands on training to local food manufacturer. He has four years of plant maintenance experience as a mechanical engineer in thermal and nuclear power industry. He has been in education for last 13 years teaching design, manufacturing, and industrial automation related courses.

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Abstract

The "flipped classroom" approach provides framework for placing more of the responsibility for foundational learning as part of a student's "homework" responsibility prior to the class meeting, thus freeing class and lab time for more active learning toward deeper application, critical thinking, and other higher-order learning. One barrier to flipped-classroom approaches has been the amount of time required for an instructor to developing adequate support for student learning outside of class. The Mechanical Engineering Technology program at Kansas State University Polytechnic is in its second year of drawing from online modules from Tooling U-SME, originally developed for technician-level learning of manufacturing technologies, to support foundational learning outside of the engineering technology classroom, as well as to assure student exposure to industry-standard manufacturing content competencies.

Tooling U course modules were mapped across the freshman and sophomore engineering technology curriculum to coincide with the two-year student subscription. Additional SME (formerly Society of Manufacturing Engineers) media library resources, included with the student subscription, fill in additional curriculum needs or depth. First-steps implementation issues include justification of student subscription cost, instructor decisions about student credit for Tooling U assignments, selection and integration of Tooling U content with additional university course activities and curriculum, and instructor or program administration of the online Tooling U course module assignments. Results of three semesters of first-steps use of Tooling U with freshman manufacturing processes and CNC students provides a case study for application possibilities, lessons learned, and future opportunities.

Flipped Classroom Support of Problem-Based Learning

Engineering Technology programs at Kansas State University Polytechnic, like many Engineering Technology programs, have a tradition of activity-based and problem-based learning. Activities during classroom and lab time, however, leave less room for instructional explanation. Students who are accustomed to project-based learning also seem to be anxious not to have to endure extensive in-class explanation. The "Flipped Classroom" or "Inverted Classroom" approach has popularized the practice of presenting content to students in some other form outside of class during homework time. Foundational concept learning is pushed to student homework time. Students then come to class prepared to apply the concepts and solidify their understanding through classroom activities, teamwork, and instructor guidance. The concept is in some ways a revival of a much older tradition of requiring students to read and learn on their own and come to class already prepared to take their learning farther with a learned instructor. Today's approach to the extended learning within the classroom places the instructor

as a "guide at the side" of engaged student activity, rather than the classic role of instructor as "sage on the stage".

Today's flipped classroom approach tends to expand beyond textbook content, emphasizing the use of more media-rich guidance to assist the students' first encounter with content material during their homework preparation. Many students require guidance to navigate reading or text material in an effective manner.

The flipped classroom has been a popular topic of paper presentation at ASEE Conferences in the past few years, but little has been shared on this topic specifically toward manufacturing-interest content.

Bishop and Verleger[1] surveyed the literature in 2013, and last year Fedesco and Troy[2] provided an updated survey. Of particular interest, Yoder[3] explored how "off-the-shelf" video content such as TED talks could support a mechanical engineering course focusing on the design process. Gehringer[4] explored commonly-available online resources and how they could be combined with various teaching strategies for instructors to develop and customize their own flipped-classroom environments and support.

Mechanical Engineering Technology (MET) faculty at Kansas State University Polytechnic had been expanding activity-based learning in the classroom, but required better support for foundational student learning outside of class. Faculty developed study guides and had wished to make their own instructional videos, but efforts proved time-consuming, slowing implementation of broader efforts.

Consideration of Tooling U as a Flipped Classroom Resource

In 2015, the faculty became aware of efforts of SME in making a subset of their Tooling U[5] online course modules available to college and technical schools program students as a two-year student subscription package. These modules[a] were selected by SME to support learning toward the Certified Manufacturing Technologist (CMfgT) exam body of knowledge. The package is bundled to include over sixty Tooling U course modules, plus access to the full SME Knowledge Edge electronic library (with recommended resources for CMfgT study highlighted), and two years of student membership to SME included.

Faculty hoped to apply Tooling U resources to increase outside-of-class learning and to build an earlier culture of student responsibility for learning outside of class. In addition to the desire to provide students with more media-rich learning resources, MET faculty also highly valued the opportunity to connect students with SME as a reliable and valuable lifelong-learning career resource.

[a] Tooling U refers to each learning module as a Tooling U "course." Within a college or university framework, this terminology can be confusing, since several Tooling U "courses" would be necessary to support a college course. For clarity, we refer to each Tooling U "course" as a module.

Table 1. 2015 Tooling U CMfgT Student Subscription Bundle Courses, matched to MET curriculum courses.

ToolingU Modules (CMfgT Bundle)	***MET Program Course Fit***
Metal Removal Processes 110	Manufacturing Methods
Cutting Processes 140	Manufacturing Methods
Manufacturing Process Applications Part 1 124	Manufacturing Methods
Punch and Die Operations 120	Manufacturing Methods
Arc Welding Processes 120	Manufacturing Methods
Drill Geometry 247	Manufacturing Methods
Manufacturing Process Applications Part 2 125	Manufacturing Methods
Tool Geometry 240	Manufacturing Methods - Extra (possibly CNC)
Milling Geometry 245	Manufacturing Methods - Extra (possibly CNC)
Product Design and Development 134	Mechanical Detailing
Product Design and Development 133	Mechanical Detailing
Intro to GD&T 200	Mechanical Detailing
Part Program 150	CNC Machine Processes
Supporting and Locating Principles 106	CNC - Extra
Fixture Design Basics 210	CNC - Extra
Intro to PLCs 200	Automated Manufacturing Systems I
Basics of Ladder Logic 220	Automated Manufacturing Systems I
Lean Manufacturing Overview 130	Automated Manufacturing Systems I - Possibility
Intro to Composites 110	Physical Materials and Metallurgy
Hardness Testing 260	Physical Materials and Metallurgy
Intro to Materials 100	Physical Materials and Metallurgy
Structure of Metals 110	Physical Materials and Metallurgy
Overview of Plastic Materials 115	Physical Materials and Metallurgy
Mechanical Properties of Metals 120	Physical Materials and Metallurgy
Physical Properties of Metals 130	Physical Materials and Metallurgy
Metal Classification 150	Physical Materials and Metallurgy
Ferrous Metals and Alloys 210	Physical Materials and Metallurgy
Nonferrous Metals and Alloys 220	Physical Materials and Metallurgy
Heat Treatment of Steels 230	Physical Materials and Metallurgy
Ceramics 250	Physical Materials and Metallurgy
Power Transmission Components 120	Machine Deisgn I
Equipment Tool Design and Development 137	???
Troubleshooting: Understanding Causes and Effects 182	???
Manufacturing Management 180	Automated Manufacturing Systems II (Seniors)
CAD/CAM Overview 160	Automated Manufacturing Systems II (Seniors)
Networking for PLCs 270	Automated Manufacturing Systems II (Seniors)
SPC Overview 210	Automated Manufacturing Systems II (Seniors)
Production System Design and Development 136	Automated Manufacturing Systems II (Seniors)
Automated Systems and Control 135	Automated Manufacturing Systems II (Seniors)
Statistics 220	Automated Manufacturing Systems II (Seniors)
ISO 9000 Overview 110	Automated Manufacturing Systems II (Seniors) - Extra
Quality and Customer Service 175	Automated Manufacturing Systems II (Seniors) - Extra

Cost Justification Constraints

In order to justify requiring student purchase of the two-year subscription (at a price of $250 per student)[b], Mechanical Engineering Technology sought to a way to use Tooling U student subscription resources in a way which replaced textbooks which students would otherwise be required to purchase. Program faculty determined that Tooling U and its related resources Tooling U and its companion Knowledge Edge Library resources would have to be used significantly, in place of textbooks, in at least two courses in order to justify requiring subscription purchase.

Table 1 details the CMfgT Bundle Tooling U course modules offered and the MET Program courses which they seemed to best support.

The "course fit" assignment in the table, however, does not mean that Toooling U was logistically feasible for each of these college courses. For example, the Automated Manufacturing Systems II course in the MET curriculum is a senior course, which would be taken by students long after their two-year Tooling U subscription expires. The modules related to this course, therefore, really cannot be taken full advantage of under the initial 2-year subscription.

In another example, faculty noted significant and helpful Tooling U modules applicable towards a sophomore physical materials and metallurgy course, but there was some concern and insufficient time to review whether content depth to determine ability to completely replace the course textbook. In such cases, other resources might fill in, but additional resource introduction and assignment creation takes time to develop, in part negating Tooling U's role in alleviating faculty of the burden of resource creation.

After examining available modules and resources, MET faculty determined that Tooling U might initially be applied instead of a required textbook within the following courses:

- Manufacturing Methods (freshman fall semester)
- CNC Machine Processes (freshman spring semester)
- Automated Manufacturing Systems I (sophomore spring semester)

Non-major and transfer students in MET courses presented an additional difficulty, as they might need Tooling U in only one class. Tooling U assisted by offering a one-semester subscription option (at $150). This has been our approach for classes such as manufacturing methods, CNC, and automated manufacturing systems.

The two-year and one-semester subscription options can only be justified for courses in which Tooling U is heavily used as the main replacement to a textbook. Some MET courses would be benefited by one or two key Tooling U modules in addition to existing text(s), but this is not feasible when students from other majors or transfer students do not already have subscription access. The usage of one or two Tooling U course modules would not be enough to justify the

[b] Prices reflect what was offered at the time and may not necessarily a reflection of current offerings by Tooling U. Organizations should consult with Tooling U concerning needs and costs.

subscription purchase, and single-module costs for the non-subscription student thus far have seemed out-of-proportion to our application needs. An example is for the mechanical detailing course. Tooling U provides modules on GD&T which would make sense with this class. In these situations, we can point out the modules as a resource available to those who have the subscription, but the lack of affordable availability to all students forces us to look elsewhere for a resource available to all students.

Implementation Issues

Course implementation issues for the instructor included:

- Identification of modules and Knowledge Edge Library resources (such as videos, support text, etc.) to best support the curriculum.
- Integration of Tooling U and Knowledge Edge assignments into the course activity expectations and grading structure.
- Developing, learning, and implementing logistics for setting up and communicating Tooling U assignments.
- Supplement of university-level content where required.

Integration of Tooling U and Knowledge Edge assignments into assigned course activity.
A major instructor consideration is the scheme employed to encourage and grade Tooling U participation and/or use of Knowledge Edge resources. In 2015 and 2016 course applications, the instructor provided assignment participation points when students achieved 80% on the module "final exam" quizzes at the end of the module. This scheme provided only minimal incentive for effort to learn Tooling U and Knowledge Edge assignments well. After gathering feedback from students, 2017 applications in the CNC and Automated Manufacturing Systems I have been assigned heavier weighting.

Equally important is actual support and integration of the assigned activity into the course content. The Tooling U modules are, in a sense, self-supporting for flipped-classroom activity. They lead students through content, involve some activity and feedback along the way, and provide opportunity for the student to test their understanding at the end of the module. If students do not first obtain an 80% or better on the final evaluation, they can restudy and attempt again. (Default settings require students to wait 24 hours between re-attempts.)

For most effective use as flipped-classroom activities, base knowledge learned by students during their study time should be augmented and reinforced in the classroom through critical thinking and active application. The follow-through requires some work on the part of the instructor to better integrate and reinforce module content with classroom activities.

In cases in which SME's Knowledge Edge library resources such as videos or readings are assigned in order to augment learning beyond the scope of the Tooling U modules, more instructor developmental work is necessary in order to provide more detailed study guides, self-check questions, or other guidance for independent study. The videos and manufacturing process resource eLibrary are valuable resources, but beginning students require guidance to help them process and retain assigned content. Study guides and practice questions are available for

the Fundamentals of Manufacturing videos, but these are typically not detailed nor interactive enough to really help students process and remember a half-hour of key concepts and terms. Development of more interactive study assistance is needed. We do note that the newest 2.0 versions of Tooling U are increasingly integrating key video footage from the Fundamentals of Manufacturing videos, which is a step in drawing together the strengths of the two separate resources.

Some of the Knowledge Edge videos applied in the manufacturing methods class (fall 2016) were:

- Measurement and Inspection
- Holemaking
- Welding
- Casting
- Forging
- Sheet Metal Stamping Dies and Processes

Results

The scope of this work thus far has been exploratory application of Tooling U module within the Mechanical Engineering Technology curriculum, with a focus on implantation issues, application possibilities, and lessons learned.

Our primary intent with the use of Tooling U-SME modules has not been directly to increase student performance of learning outcomes. Rather our initial intent has been to:

- to expand student exposure to industry-standard manufacturing content and competencies.
- to challenge students to greater self-directed learning.
- to open up new venues of classroom activity and learning opportunity.

These benefits would support conclusions in the study by Fedesco and Troy,[2] that transformative learning happens with flipped strategy, not just numerical improvement.

Application of the Tooling U modules has been evolving. In the classes where it has been applied, it has shifted and expanded some content focus as we have adapted greater use of the modules and SME-Knowledge Edge Video resources. Early application in Fall 2015 was sporadic due to the instructor learning curve, but has been increasing with instructor familiarity, and most certainly with the second-year opportunity to explore an expanded set of Tooling U content. Exams and other outcomes assessment instruments have evolved to match content, creating dissimilar measures. Comparison of student performance with previous text-based approach likewise is a problem of comparing dissimilar content evaluated with dissimilar assessment tools.

The content either from text or Tooling U in these classes is generally intended to extend content and vocabulary learning and concepts beyond what is practiced in the applications projects. The measures from the applications projects, therefore, do not provide an adequate reflection of the success of the modules or other content learning.

It is therefore not our object at this point to prove an improvement in SLO attainment. Rather, we discuss here some of the lessons learned, application successes opened by the content, and future opportunities.

Administrative learning curve. Tooling U was very proactive in offering regular assistance and web demonstrations, but we found there was a bit of an experiential learning curve in setting up student access and assignments more effectively.

One of the most helpful things we learned very late was to ask for a sample student login to add in with other students in the class list. This not only allows the instructor to check whether assignments and access have been setup correctly; it also allows the instructor to demonstrate to the class how to access their assignments and other resources.

Content struggles, adjustments, and strategies. Faculty understood at the outset that Tooling U module depth of content would not always be at a depth required for four-year engineering technology practitioners. We were prepared to augment with some detail. However, we found that the limited content of the CMfgT bundle presented unexpected struggles in using the materials to the extent required for textbook substitution. The Tooling U course modules required for CMfgT study are often overviews which do not necessarily match the depth expected for particular technology topics. For example, the CMfgT bundle only provided two overview-level CNC modules. We knew Tooling U had other modules more specific to our more detailed CNC course needs. Likewise, the CMfgT bundle was surprisingly brief on various manufacturing processes.

Tooling U representatives have been gracious in learning about four-year college needs and for the 2016-2017 academic year offered on a temporary basis for our program to explore using other Tooling U modules beyond the CMfgT bundle. Some of the modules beyond the CMfgT set which we have found useful in the manufacturing methods course include:

- Overview of Machine Tools 121
- Basic Measurement 101
- Grinding Safety 211
- Bending Fundamentals 120
- Overview of Weld Types 221
- Welding Symbols and Codes 250

Access to this broader selection dramatically improved our ability to use Tooling U modules to reduce lecture time as originally intended. It also allowed us to use Tooling U more at a level in keeping with the monetary investment made by the students.

The augmented course access also provides expanded resources planned for the CNC and sophomore automation course, making cost-effective implementation more realistic for these courses as well. At the time of this writing, the modules adopted for these courses have substantially increased the expectations for student learning of standard terminology and

concepts underlying our regular project-based learning. We are in mid-implementation of this semester and have yet to realize and measure results.

Student responses.

One unexpected student response has been interest by selected students in working through the modules to take the CMfgT exam, or simple to obtain the certificates awarded with each module.

One hoped-for result was increased student awareness of the importance of industry-standard "body of knowledge" content presented by Tooling U and SME resources. Having basic content presented by SME as an authority did seem to be treated by the students as having more relevance and importance than handouts prepared and presented by the instructor in previous years. Some students did respect elements of the Tooling U content as something that would be expected and appreciated by future employers. Students have begun to ask in the lab questions that reflect specific technologies they studied in Tooling U. For example, in past years, students have paid little attention to text material introducing cutting tool angles, but in fall 2016, students sometimes asked about these when they were doing their work. Something about the presentation with Tooling U was able to engage student interest and application back toward their lab work in a way that previous text material missed.

Student usage where Tooling U was not required. We set up for existing subscription students "Resource Pack" courses for materials and fluid power courses which used other resources (textbooks) and which did not require Tooling U. An email attempted to get the word out to these students that they had access to the Tooling U study resources, but we were not effective in getting students to make use of these. It might have been more helpful if we had trained the course instructors in how to demonstrate resources of interest to the students. We also note that this was offered for students who had a much more minimal Tooling U experience in our first rollout of Tooling U in fall of 2015. Students with a more extensive and satisfying experience with Tooling U in required classes may find more interest in Tooling U resources, even when not required.

Future opportunities. As our program has been improving the larger curriculum in response to industry feedback and internal assessment feedback, the availability of the modules has increased our opportunity to implement specific content needs into courses where it has not existed in the past. Examples include:

- **Welding symbols** – As our program is in a region which heavily applies welded sheet metal processes, our Industrial Advisory Board requested better student exposure to welding symbols. A Tooling U module that introduces and assesses initial student introduction to welding symbol application and interpretation has made it easy to respond to this need.

- **Lean manufacturing** – We have long known that our curriculum waits too long to expose students to lean manufacturing principles (in the senior year), but we have previously had difficulty getting introductory lean concepts into earlier courses. The availability of modules introducing lean, along with an excellent library of videos, is

making it feasible to slide this into an expectation for students to study outside of the sophomore automated manufacturing systems class without distracting from class time on the technical automation content.

- **Safety** – It has been a struggle to incorporate safety content with justice into an already-packed curriculum. The modular approach makes it easy to insert industry-relevant safety content, including industry relevant photographs and applications. For example, in Fall 2016 a Grinding Safety module allowed students to get far deeper into this topic than we ever have in the past.

Conclusions

Tooling U modules selected appropriate to course needs can provide useful "flipped classroom" resources, placing the responsibility for first-exposure to course concepts on the student during their own homework time. Reduction in the need for the instructor to introduce basic concepts can free class time for more application and project needs. However, instructor reinforcement may be helpful for overall learning.

Access to an extended set of Tooling U courses may provide sufficient content depth and breadth necessary to substitute for textbook purchase for a manufacturing processes, CNC, or basic automation course. The smaller CMfgT student bundle, though overall a good overview resource for those interested in testing for Certified Manufacturing Technologist certification, offers only a limited number of course modules applicable to any one traditional mechanical course, making it difficult to cost-justify as a textbook substitute within a particular course.

The expanded set of courses meets our needs for bringing specific industry-relevant and sometimes technology-specific content into courses which had been a struggle to incorporate in the past. Student-initiated discussions indicate that the SME-branded content has also increased student awareness for industry expectations and the relevance of content to their careers.

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