AC 2010-638: CREATE YOUR SCENARIO INTERACTIVELY (CSI) – A TEACHING MODULE FOR MANUFACTURING PROCESSES

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Abstract

Students can learn more effectively when they are actively involved in the learning process. The traditional approach is mainly "teacher-centered" and lacks in the nurturing of students' skills in today's changing world. Various non-traditional approaches such as project-based, problem-based or case study-based learning have been developed and found to improve students' learning engineering concepts. In this paper, we discuss the impact of scenario-based education on students' learning manufacturing engineering and the retention of engineering students. **C**reate your **S**cenario **I**nteractively (*CSI*) is a novel concept expected to (i) stimulate active learning, (ii) provide an engaging learning experience of engineering concepts by allowing students to visualize and interact with 2D/3D objects, (iii) prepare students to solve open-ended problems in industries, and (iv) serve as a natural link to subsequent courses in the STEM disciplines. We discuss some initial research results on the *CSI* module development, implementation, and evaluation plan for teaching manufacturing engineering course at University of Oklahoma and Tuskegee University. The pedagogical effectiveness of the CSI system covering four different areas - (i) students' learning, (ii) students' attitude towards engineering, (iii) retention of students, and (iv) usability of the CSI system are also discussed.

Introduction

Over the years the U.S. engineering schools are facing decline in students' enrollment and graduation rate with the exception of top academic institutions [1-6]. This trend is not only related to the level of complexity associated with science and engineering education, but also the medium of instruction practiced which often leads to the students' lack of willingness to learn abstract engineering concepts. For example, the materials and manufacturing course is offered in both the University of Oklahoma (OU) and Tuskegee University (TU) in a traditional style and is found that the students often have difficulties understanding abstract concepts and lose their interests. The medium of instruction that engages students' learning complex engineering concepts is necessary in today's changing world.

Learning through a medium that combines course materials with interactive visualization and simulation is proven to be a very powerful tool for engineering education. According to recent NSF funded projects it has been found than students learn best when (i) presented with organized information that relates in some way to their own experiences, and (ii) they are given the opportunity to test themselves on their own understanding and to work to develop their understanding with other students [7]. Our high school and undergraduate engineering students in the 21st century are growing up in an era where interactive role playing, and goal centered scenario (SimCity) video and computer games have been one of the major components of the entertainment industry. Survey results show that about 60% (**40% of which is female**) of the U.S. population play video games

[8]. It has also been reported that the game approach in education has potential to capture students' interests and improve learning and teaching methods [9-10]. Sanderson and Millard [9] applied a team-based game strategy in manufacturing education, where students/users assumed the roles of product designer, manufacturing engineer, marketing expert, and product manager. Hsieh [10] investigated a web-based 2D game environment for teaching line balancing concept. It was reported that the game concept has enhanced student interest in learning the materials.

In this paper we discuss a novel concept "*Create your Scenario Interactively (CSI)"* in engineering education. The *CSI* is an interactive storybook-like learning tool which is composed of interactive storyline, 2D/3D visualization, simulation, and state-of-the-art interactive technology. The CSI system (i) encourages active learning; (ii) bridges the gap between theory and practice; (iii) develops key skills such as communications, group working and problem solving; (iv) improves the image engineering; and (v) attracts a greater number of students to pursue engineering degree. The interactive scenario based learning is not new, for example, infants learn through interactions with small toys, stories, and educational games (e.g., Sesame Street website). Many or most engineering students are visual, sensing, and active whereas conventional engineering education is auditory, abstract (intuitive), and passive [11]. Since the *CSI* fits very well with the learning style of majority of the engineering students, it will (i) provide an engaging learning experience for students by allowing to explore, interact and develop a design scenario; (ii) allow interaction with scenarios and provide immediate and constant feedback to student's actions, which has proven to make learning more effective [12]; (iii) expose students to the type of challenges they will face in industry. This active problem solving experience in meaningful real-world contexts can greatly enhance students' learning [13].

Significance of CSI

The *CSI* is different from the conventional blackboard, power point based lectures, and e-learning method [12]. Compared to e-learning software, the *CSI* allows students to easily explore all the options, boundaries, and solution space for a given open-ended problem. The *CSI* offers interactions in the form of exploring options, and how different options can lead to different solutions for the same problem. It will provide students with instant responses and reflection based on design requirements and student backgrounds. The *CSI* uses characteristics of role playing and scenario-based games and several commercial software (e.g., Pro-Manufacturing, etc.) and combines them to illustrate manufacturing processes and engineering designs. Reasoning behind the answers are solicited from students and weighted by instructors during grading. This is to overcome one of the common pitfalls of game-based learning: that students concentrate too much on completing design and become distracted from learning. Thus, students can explore alternate design decisions and results from other groups to gain a better understanding of the material using web-based *CSI*.

CSI System Description

The *CSI* system has two basic issues: the housing and software. The housing of the *CSI* environment is an important consideration that affects students' interest. In the proof-of-concept stage, the *CSI* will be implemented in a regular classroom with different student groups using laptops with wireless Internet and the instructor using a laptop to monitor student responses and a projector (*most universities have this capability*) to share development of stories/scenarios from different groups. Students will use their own laptop in class (most engineering students have their own laptop). The commercial software to be used includes Pro-E, Pro-Machining, Pro-mold, Flash, multi-user communication server, web-based technologies, and inhouse software including the basic modules.

Information Flow

In a class, instructor presents a scenario to attract students' attention. The scenario addresses a real problem, but easy to understand and relate in some ways to their own experience. The instructor analyzes the problem and provides the theoretical background information which can also be accessed anytime during/outside the session. A 3D solid model of the scenario is presented for better perception and overall objective of the project. Now students address the relevant issues systematically in the *CSI* environment as a group or individual setting and provide justification for their design and manufacturing decisions. Effects of each decision at each step are enhanced by simulations and visualization tools. The *CSI* system implements an adaptive progression system that allows students to progress forward if correct reasoning for each sub-question is reached. These reasonings show whether students have fully understood the theoretical contents. Students can repeat the scenario up to a limited number of times for each step. Web-based point scoring system helps the students and instructors to be aware of difficulties associated with specific concepts. A set of learning questions are available for students for review any time. An example to illustrate the CSI course module is shown in Figure 1.

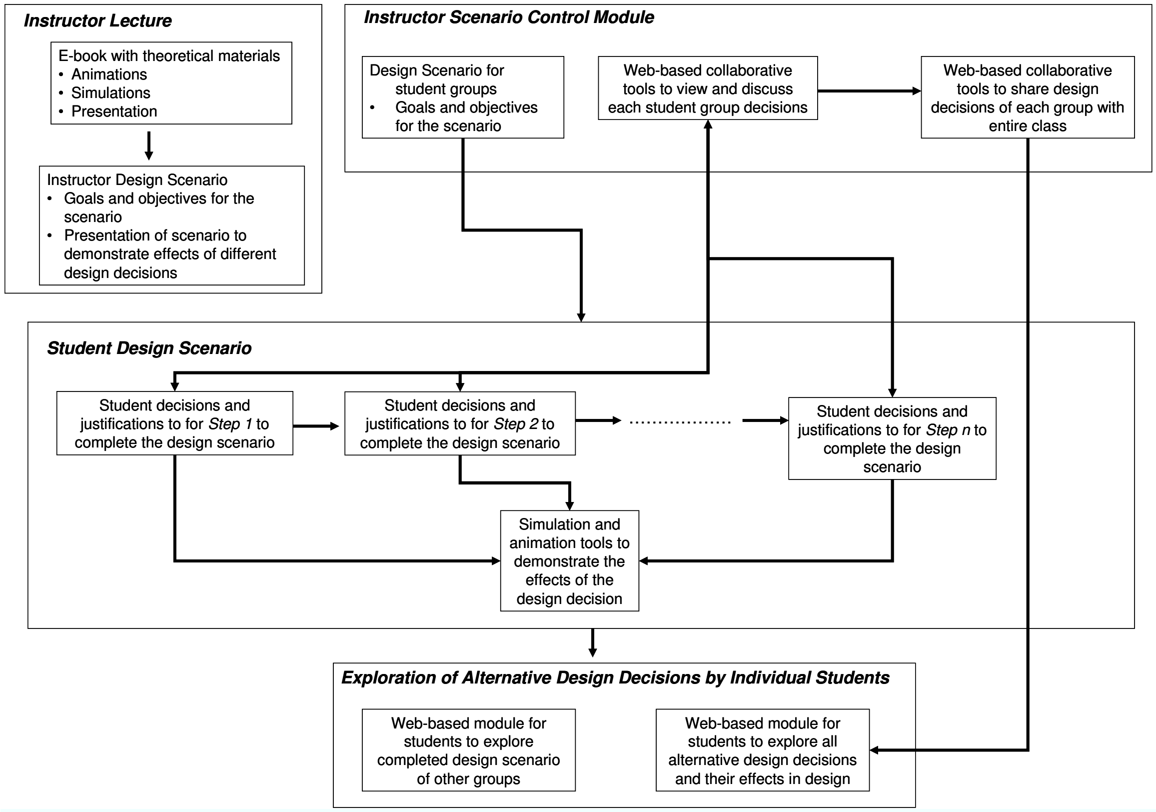


Figure 1 – Flow of activities in the *CSI* environment

Module Development for Metal Casting

As a "proof-of-concept" the *CSI* module is being developed to teach *metal casting* in two undergraduate courses: AME2303 at the University of Oklahoma (OU) and MENG0314 at Tuskegee University (TU) starting at the spring 2010 semester. Fundamental understanding on *metal casting* requires mastery of four major concepts: (1) flow and heat transfer characteristics of liquid metals in the mold; (2) mechanics of solidification of metals and alloys; (3) defects in casting; and (4) mold deign, and the *CSI* module discusses all four major concepts in various sub-modules. Each module contains theoretical and fundamental information which the students can access any time during the interactive session. Several real casting problems will be presented as scenarios with clear goals and design constraints addressing effect of materials, geometric tolerances, component shape, tools, and other process parameters. Students will interact with the *CSI* environment towards solving the problem as a group where multiple solutions exist and will be shared with other groups and will be discussed.

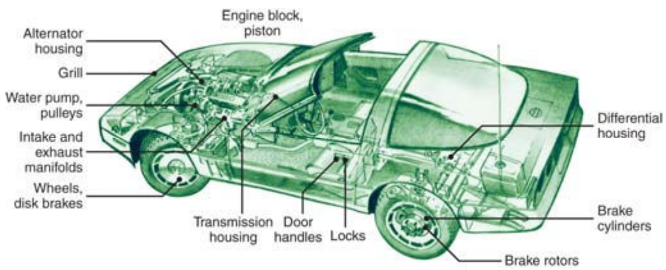
Table 1: Construction of the *CSI* module

CSI sub-module	Related topics	Resources
Flow module	Liquid metal flow Theoretical Considerations Fluidity	Interactive Examples Instructor Notes
Solidification module	Solidification of metals/alloys Phase diagram Solidification in mold Microstructure and property Cooling and heat transfer	Interactive Example Instructor Notes
Defect module	Shrinkage Type and source of defects Porosity Internal and external chills Inspection	Interactive Examples Instructor Notes
Design modules	Types of casting and mold Mold design and fabrication Design guidelines Economics	Interactive Examples Instructor Notes

Classroom Implementation

The selection of the scenario and organization of information is very important for the success of the *CSI* environment. Since the automobile is very familiar to our students, the piston, crankshaft, or engine block is an appropriate scenario for metal casting as shown in Figure 2a. Complexity of the cast parts in terms of size, shape, location of cavities, etc. will be introduced and the importance of net-shape production and cost-benefit will be discussed. Also, the functionality of these cast parts in an internal combustion engine will be discussed. Pistons must be manufactured at a very high rate with very tight dimensional tolerances and strict material/functional requirements in order to achieve proper operation. The capability of the casting process to produce near-net shaped "piston" will also be demonstrated in Figures 2b-c and the related design, materials, and manufacturing issues of casting process will be discussed. For example, aluminum alloys are preferred over other metals for several reasons: light weight, high thermal conductivity, high resistance to corrosion, etc. However, with poorly designed mold, underfills or excess porosity can cause parts to be rejected, thus adding to the cost. Surface defects may require additional operations such as machining which can reduce the production rate and cost of the part. We believe that the student will appreciate the importance of casting process in our daily lives and will be encouraged to learn more about casting process. The immediate and most important challenge would be now "***how***

can the CSI module make them engaged through active participation in learning casting process?”



(a)

(b) (c)

Figure 2: Presentation of the scenario for casting: (a) cast parts in a typical automobile, aluminum piston (b) as cast, and (c) after machining.

Once the scenario is presented, a set of design requirements for the piston will be given and the students will be asked to go through various synthesis steps to solve the problem. During the process, interactive simulations and animations will be presented to relate the theory with each synthesis step. For example, selecting a material for casting process requires the understanding of solid solution and solidification of binary metals (in case of alloys). Thus, in the *CSI* module, the students will select the *solidification module* where the concepts are presented systematically to cover the related topics. A general introduction of alloying and heat treatment concepts will be introduced for further understanding and controlling of microstructure during solidification. Along this line, structure-property relationship will also be discussed with emphasis on the effect of cooling. To demonstrate their learning related to the solidification concept, the students will be asked to specify casting material for the piston scenario based on solidification to meet specified requirements and, if needed, the entire process will be repeated until the solid foundation on the subject is reached. A “time-scoring” system will guide the students to reach the level of confidence on the concept. Thus the effects of different design decisions related to materials will be covered within the umbrella of the *CSI* module. Once the materials concepts are understood, students will be asked to choose *fluid module* where effects of various casting parameters such as fluidity of the metal, viscosity, temperature, etc will be discussed. Appropriate theoretical background such as Bernoulli’s equation, mass continuity, Reynolds number will be presented systematically. Students will be asked to specify parameters for different components of the mold for the piston scenario based on the theoretical concept and the level of confidence will be scored. Solidification of metals inside the mold will be introduced with respect to mold and sprue design, design of risers and inserts, and will be tied with other physical properties of material such as shrinkage and porosity on the part. Similarly a good amount of time will be spent on the design of the mold and mold materials and the concept of economic design satisfying the functional requirements of the piston. Different design solutions proposed by different students will be discussed in the class and the reasoning will be given, to better understand the correct approach for specifying material, mold and other casting parameters.

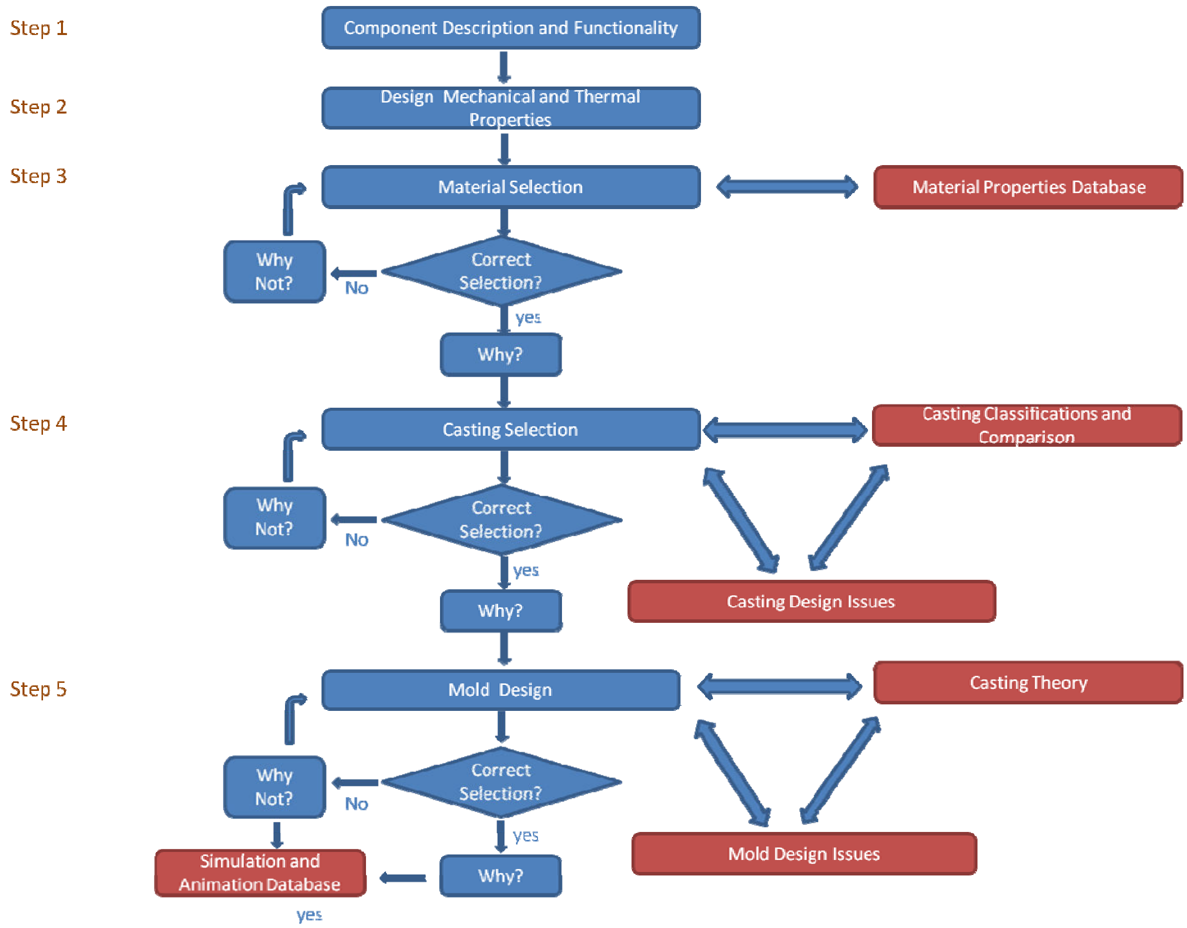


Figure 3: Casting scenario flow diagram

Answers for different steps of the scenario (Figure 3) will be collected from the students and discussed in the class to collectively understand different aspects of metal casting. Web-based tools will be used to develop different components of the *CSI* environment. Flash and .NET will be used to develop the user interface for the web-based scenario. The scenario created by the students will be stored using Access database. A graphical representation of the *CSI* module in classroom environment showing scenario presented by instructor and students developing their own design scenario is shown in Figure 4.

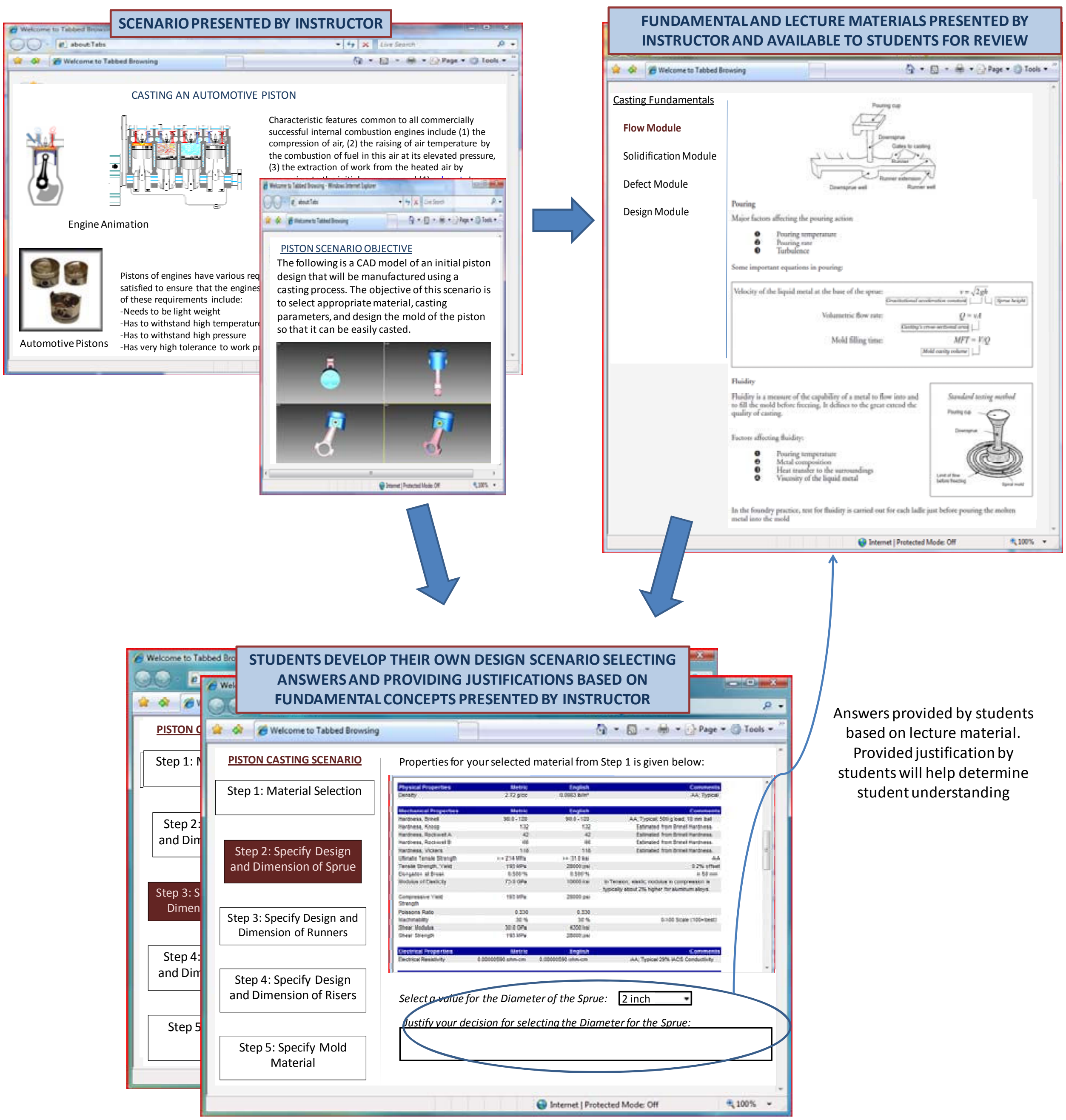


Figure 4: Classroom implementation of the proposed *CSI* module for instructor and students

Module Example – Mold Filling

To demonstrate the mold filling in metal casting we consider a mold that is very simple yet shows all possible complexity as shown in Figure 5. Using 3D simulation both instructor and students can analyze the mold by viewing the cross-section at different angle. Basic understanding of the mold design, and different parts of the mold are demonstrated. To demonstrate the effect of height on mold filling, temperature, and velocity distribution, we designed a very simple mold filling model and generated the snap shots and Figure 6 shows some screen shots of metal casting process as a function of time. Students can visualize the metal flow into the mold and gain some insight on the mold design. Once the mold is filled with hot metal the solidification will begin. Figure 7 shows some snap shots of temperature distribution during mold filling. As temperature distribution plays important role in developing the residual stress, students will gain some insight on the design of metal casting component. For example, non-uniform thickness or too thick of a component near the center will cool down too slowly as compared to the materials on the surface. This will result in residual stress which can lead to wrapping of the parts during secondary processing. Different color coding will differentiate the spatial distribution of temperature profile. Any region shows too low or too high temperature may be a point of interest for redesigning of the part. Another important parameter in metal casting is the velocity distribution of metal as it flows into the mold. Figure 8 shows some snap shots of velocity distribution profile. Fundamental understanding on laminar or turbulent flow of liquid will be augmented through a demonstration of these snapshots. Any sudden jump in the cross-section will result in loss of kinetic energy which may result in formation of void or other forms of defects. Too much velocity may also cause erosion of mold materials and result in unwanted surface defects.

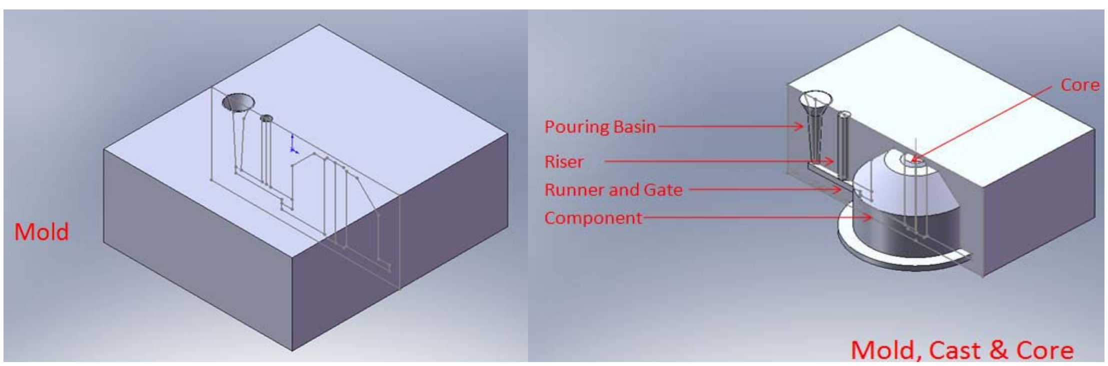


Figure 5: CAD model of mold and component to be cast

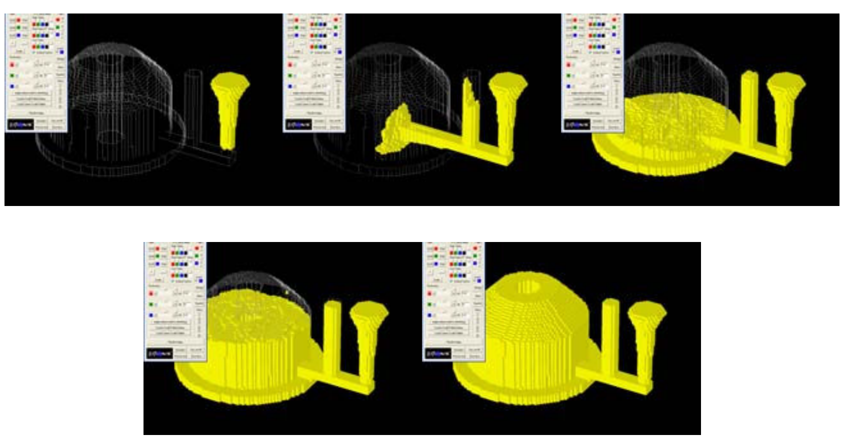


Figure 6: Metal flow demonstration

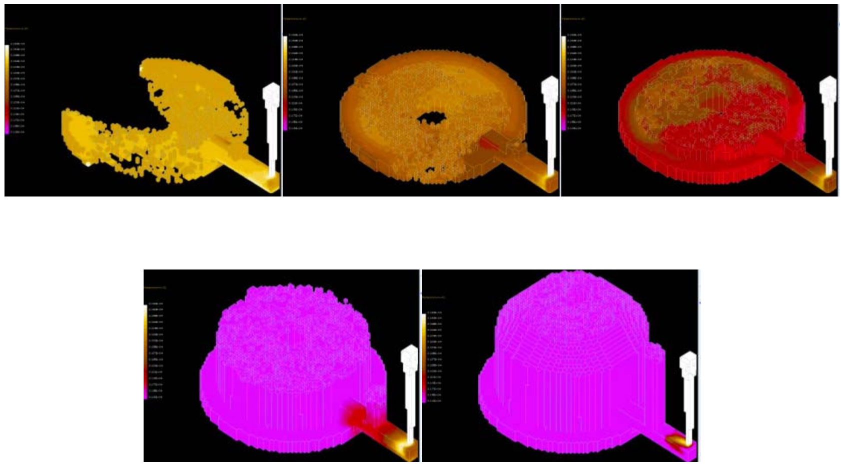


Figure 7: Temperature distribution during mold filling

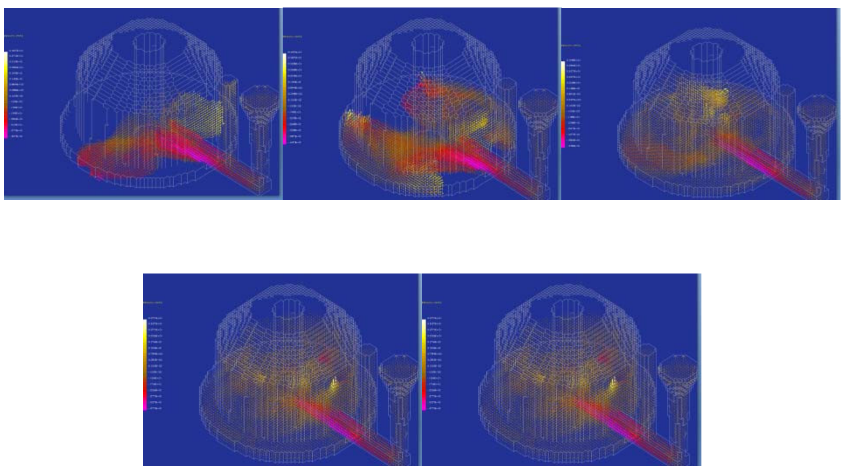


Figure 8: Velocity distribution during mold filling

Module Assessment Development

Along with the course module development and implementation, an innovative evaluation system with formative and summative evaluation techniques based on both subjective and objective data will be used to test the *CSI* systems' pedagogical effectiveness, student attitude change, and retention. To understand whether *CSI* system can improve students' learning and retention of course materials covered, evidence of the students' learning outcome will be measured, analyzed, and compared with the conventional methods. Performance of students on quizzes, tests, and projects will be compared between the course implemented with the *CSI* system and the same course with conventional lecture format. Based on the (a-k) ABET criteria specific student learning outcomes will be determined jointly by faculty members who had taught these courses. Then, survey items, and open-ended questions in an assessment tool will be developed based on these learning outcomes to assess the students' learning. Individual interviews will be conducted with students taking the courses to get their opinions about using the *CSI* system. Feedback from the students will be used as basis for improving the *CSI* course modules in the future. The teaching module in the *CSI* will contain a set of short questions to determine which concepts were well understood and which were not. Student's scores on these questions will help the development team to determine areas of improvement for the *CSI* system

To assess the impact of the *CSI* on students' attitude towards engineering and students' attitudes towards engineering before and after taking the *CSI* course modules will be measured through standardized surveys and interviews [14-15]. The *Sophomore Engineering Learning and Curriculum Evaluation Instrument*© will be administered to students taking the sophomore level course AME2303 at OU and MENG 0314 at TU. Structured interviews with students will be used to get more insight on the reasons causing their attitude changes. Data of students from different gender and ethnic groups will be analyzed to study the attitude difference between gender and ethnic groups.

In order to assess the impact of the *CSI* system on the retention of students, data on retention rate of the AME students at OU and ME students at TU will be collected. The retention rates of the students exposed to the *CSI* system will be compared to historical retention data to determine the effect of *CSI*.

To ensure an engaging and satisfactory student learning experience, throughout the development of the *CSI* system, usability evaluation methods will be applied [16-17]. During the early development stage of the *CSI* system, heuristic evaluation methods will be used to evaluate the scenario design aspects including interface, story, and mechanics. When the *CSI* system takes shape, laboratory-based user testing sessions will be conducted with students, followed by satisfaction questionnaires and interview. User's comments, failures, and subjective feelings will be used to identify design characters leading to positive and negative user experience.

Conclusion and Future Work

In this paper an interactive scenario based learning environment has been presented. The **C**reate your **S**cenario **I**nteractively (CSI) module has been developed to actively involve students in the learning process and to enhance the learning experience. The CSI is expected to (i) stimulate active learning, (ii) provide an engaging learning experience of engineering concepts by allowing students to visualize and interact with 2D/3D objects, (iii) prepare students to solve open-ended real-world problems in industries, and (iv) serve as a natural link to subsequent courses in the STEM disciplines.

The CSI module is currently under development and will be implemented, tested and validated in Design and Manufacturing Processes courses offered at the University of Oklahoma and Tuskegee University.

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