ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

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Paper ID #14954

Design and Development of Online Applied Thermo-Fluid Science Courses

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Abstract

Online teaching and learning has become a popular pedagogy for educators and students due to the flexibility and accessibility of course materials. Many educators revised and redesigned their courses and the methods of teaching to convey their courses online. Course management systems such as Blackboard, Moodle, and many others are widely adopted by universities and colleges to provide a platform for educators to offer their courses in online settings. In addition, textbook publishers have started to develop and offer teaching resources such as; lecture slides, question banks, quizzes, and exams to assist online teaching. Although platforms and resources are available to support online teaching, designing, developing, and teaching online courses in engineering technology fields remain a challenge due to the applied nature of the courses and the compatibility of the teaching resources. This paper will discuss the design and development of online undergraduate level Applied Fluid Mechanics and Applied Thermodynamics courses in the Mechanical Engineering Technology Department at Farmingdale State College. It also sets the groundwork to measure the effectiveness of the online setting for these courses. Assessments of both courses in online and in-class settings will be conducted in the near future after the authors have taught their courses in both settings for at least one time.

Introduction

In recent years, the demand for accessibility in higher education has been on the rise. Many higher education institutions have been redesigning their courses and curriculums to meet the needs of growing enrollments. This has resulted in a shift from traditional in-class teaching to hybrid or fully online teaching. Also, as the accessibility to Internet increases in the modern age, online education has quickly become a popular pedagogy [1-3]. Online course settings not only are able to offset the growing enrollment, they also offer several advantages over the traditional in-class teaching. One of the main advantages is the flexibility and accessibility of course materials. Both traditional and non-traditional students can have the flexibility of learning the materials at their own time that do not conflict with their day-to-day activities. In addition, online course settings allow students to learn the course materials at their own pace without being forced to follow the pace of the instructor or the class [4-6].

Although online education has its own advantages, the effectiveness of student experience in online settings compared to in-class settings is questionable. Researchers around the world have been studying the effectiveness of online education [7-10]. Traditional in-class setting is in a professor-centered learning environment; where the professor teaches the theoretical component of the course and explains the materials to the students directly within the limited class hours. Also, the practicum component is carried through the hands-on laboratory setting. The interaction in this setting is direct and active. Traditionally homework assignments, quizzes, exams, and laboratory reports are used to assess student learning in theoretical and practical components, respectively. Online setting however is in a student-centered learning environment where students learn the prearranged course materials at their own pace. The main challenge in this setting is the lack of direct faculty-student interaction and the requirement of independent and self-motivated students. It requires a collaborative effort between the instructor, the student, and the class. [4, 5, 11].

Successful interaction in an online setting can be achieved by implementing a variety of learning activities such as: group problem solving, discussion boards, simulations, case studies, group projects, and brainstorming sessions [12]. Although these components serve as a great addition to the online courses; certain course-specific challenges tied to the online course-settings still needs to be addressed by the course instructor. Especially for science, engineering and technology courses where the courses have a practicum component in addition to the theoretical component, or the course topic requires undivided student attention or certain level of mastery in mathematics and science. These challenges have been addressed in many different ways. In an effort to overcome the challenge of offering practicum component in online courses, virtual laboratories, simulation-based laboratories, and remote access laboratories for many courses such as: Fluid Mechanics [13-15], Thermodynamics [16, 20, 22], Circuit Design [17], Mechanisms and Machine Dynamics [18], Materials Science [19], and Control Engineering [21] are developed and implemented by the educators.

In addition to the practicum component, another challenge of online courses is to create a learning environment where instructors can capture students' undivided attention. In a traditional classroom setting, the course instructor has the advantage of interacting with students in a face-to-face setting to observe and respond to student interest while teaching. As an example, if the course instructor feels like students are getting lost in the material, he or she can repeat the theory or provide additional examples, or engage students in an in-class discussion. In an online setting, the course instructors are distant from the students, and do not get a chance to observe them while students learn the material. Instructors in this setting should be more creative in the ways they convey the course materials. Providing just lecture slides or reading assignments from the book may not be sufficient.

This paper compares the traditional and online settings of Applied Thermodynamics and Applied Fluid Mechanics courses offered in the 4 year Mechanical Engineering Technology program at Farmingdale State College. The paper also provides an overview of the two online courses along with the development of interactive online teaching materials such as lecture notes, examples, assignments, simulations, animations, and discussion boards for the courses.

Design and Development of the Thermo-Fluid Science Courses

Applied Fluid Mechanics (MET 212) and Applied Thermodynamics (MET 314) are core courses offered in the Mechanical Engineering Technology Department at Farmingdale State College.

Both courses are required for the Mechanical Engineering Technology B.S, and Facility Management Technology B.S. Programs. Applied Fluid Mechanics requires Calculus I with applications as a prerequisite course and College Physics II (Algebra based Physics) as a co-requisite course. Applied Thermodynamics requires Calculus I with applications and College Physics II as prerequisite courses. Since the courses are designed for engineering technology students, the co-requisite and prerequisite for them is the algebra based physics course and the use of calculus in these courses is minimal. Due to the limited class hours, the authors focus the teaching materials mainly on the fundamental of the subject matters instead of overloading students with mathematics and the subject matters at the same time.

Due to the high demand of part time students who cannot take these courses during the regular hours, the department has decided to offer both courses alternatively between in-class and online settings every semester throughout the academic year to address the needs of different types of students. The typical class size for both courses is about 25 students whether it is in an in-class or online setting. The authors Dr. Gonca Altuger-Genc and Dr. Jeff Hung are the instructors for the Applied Fluid Mechanics and Applied Thermodynamics courses, respectively. They have taught their own course in an in-class setting for at least one semester before developing their online course. This is to ensure that they have the experience of teaching the course as well as the understanding of the level of their students.

The online Applied Fluid Mechanics and Applied Thermodynamics courses were developed and delivered through Blackboard, a web based course management system. Both courses use standard textbooks that are commercially available on the market. The two online courses have similar course structure to provide students with similar learning environment. The courses are module-based where the teaching materials for each chapter such as lecture notes, examples, assignments, interactive activities, and visual demonstration are grouped into a module. It is important to note that the development of courses did not limit the academic freedom of the authors in the methodologies and tools they employ when they are teaching online. For consistency, the course objective, student outcomes, and course content remain the same whether students take the course in an in-class or online setting. The only difference is the student assessment and grading policy. In addition, with the online courses, there is always the challenge of confirming whether the student enrolled in the course is the same student taking the course. A possible solution is to set-up common exam times for the course. However, this defeats the purpose of the online course and it is impractical to find a common time for all students. Authors have developed many course assessment activities such as reading assignments, homework assignments, discussion boards, and exams in the online courses to monitor the continuity of the learning process. This reduces the possibility of having someone other than the student taking the course. Also, the advanced sequential thermo sciences courses such as Applied Heat Transfer and HVAC courses will require the basics learnt in the Applied Fluid Mechanics and Thermodynamics courses. If a student had someone else taking the online course for them, they will have very difficult time in learning the materials in the advanced sequential thermo-science courses because these courses are mainly offered in person. The following sections discuss the Applied Fluid Mechanics and Applied Thermodynamics courses.

Applied Fluid Mechanics Course

Applied Fluid Mechanics course teaches the fundamentals of fluid mechanics concepts and covers the nature of fluids, forces due to static fluids, buoyancy, Bernoulli's Equations, Reynolds Number, Laminar flow and Turbulent flow, drag and lift, and flow of air in ducts, blowers and compressors. The course uses Applied Fluid Mechanics Seventh Edition by Robert L. Mott and Joseph A. Untener [23] as the course textbook. Throughout the course, thirteen chapters from the book are covered. The course requires students to read corresponding chapters from the textbook throughout the semester; in addition, the entire lecture slides and examples that are covered in the classroom are shared with students through the course page on the Blackboard platform.

In-Class Setting Course Components for Applied Fluid Mechanics

During the in-class setting of the Applied Fluid Mechanics course, the course follows the course textbook and has weekly homework assignments, 2 quizzes, 1 mid-term and 1 final exam. The lecture slides and in-class problems are shared with students through the course page in Blackboard, this ensures that students have continuous access to the lecture slides and in-class problems throughout the semester. The assessment of the continuous learning is conducted through weekly homework assignments. The quiz and mid-term exam questions are reviewed in the class following the assignments to ensure the continuity of the learning process. An overview of the learning loop for the in-class offering of the course is shown in Figure 1.

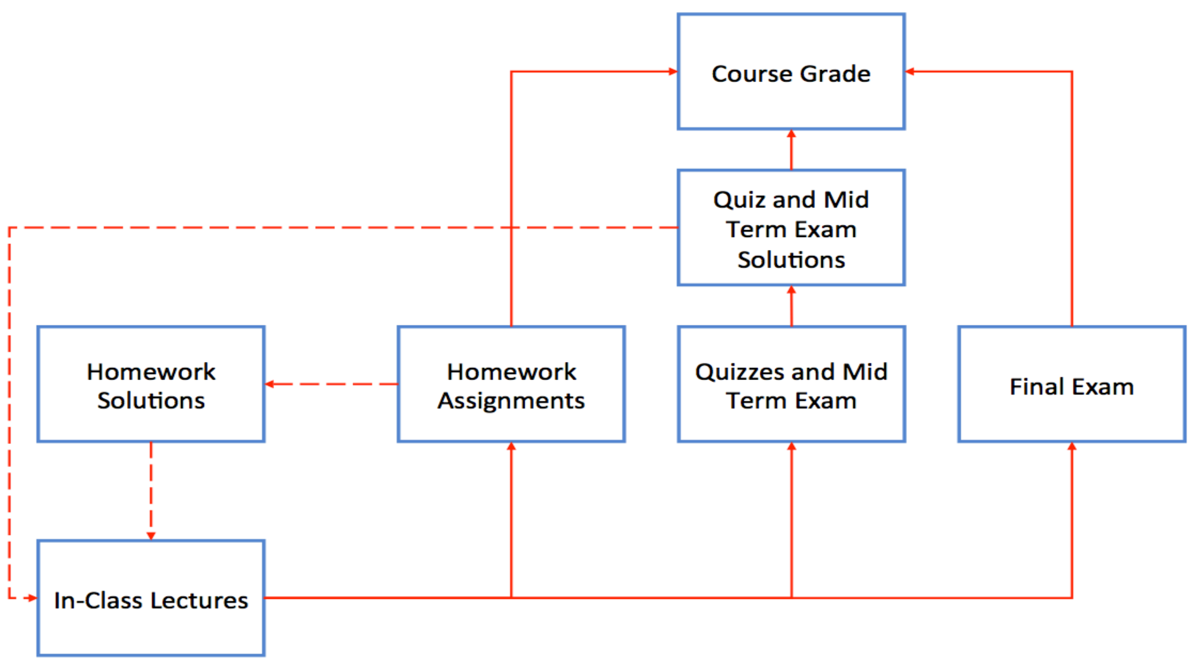

Figure 1. Overview of Learning Loop for Applied Fluid Mechanics Course (In-Class)

Online Setting Course Components for Applied Fluid Mechanics

In the online setting of the Applied Fluid Mechanics course, the theoretical component of the course is taught by the course instructor via lecture slides and additional learning materials. The lecture slides cover the theory while the additional learning materials such as additional reading materials, additional examples and any related virtual and interactive simulations and animations provide students a better learning experience. The assessment of student learning is conducted in each module through homework assignments, quizzes, class interaction activities and module review questions. The module review questions and class interaction activities are designed as the initial assessment of the learning materials. Upon reviewing the learning materials, students complete the module review question and participate in the class interaction activity. Upon completion of the initial assessment, students can complete the homework assignment and the quiz. The homework assignments and the quizzes have a built in feedback loop. Students are given two attempts for both homework and quiz assignments. The homework assignment is not timed, students have unlimited access to homework assignments for each attempt where they can pause the homework and review the learning. The quiz has 75-minute time limit and must be completed in one sitting. Upon completion of the first attempt of the quiz, students are provided with answers and feedback on the questions they have completed. Based on the feedback they received, they can review the material or contact the professor to review their solution process. When ready, they complete their second attempt. In terms of grading, the highest grade of the two attempts counts. An overview of the learning loop for the online offering of the course is shown in Figure 2.

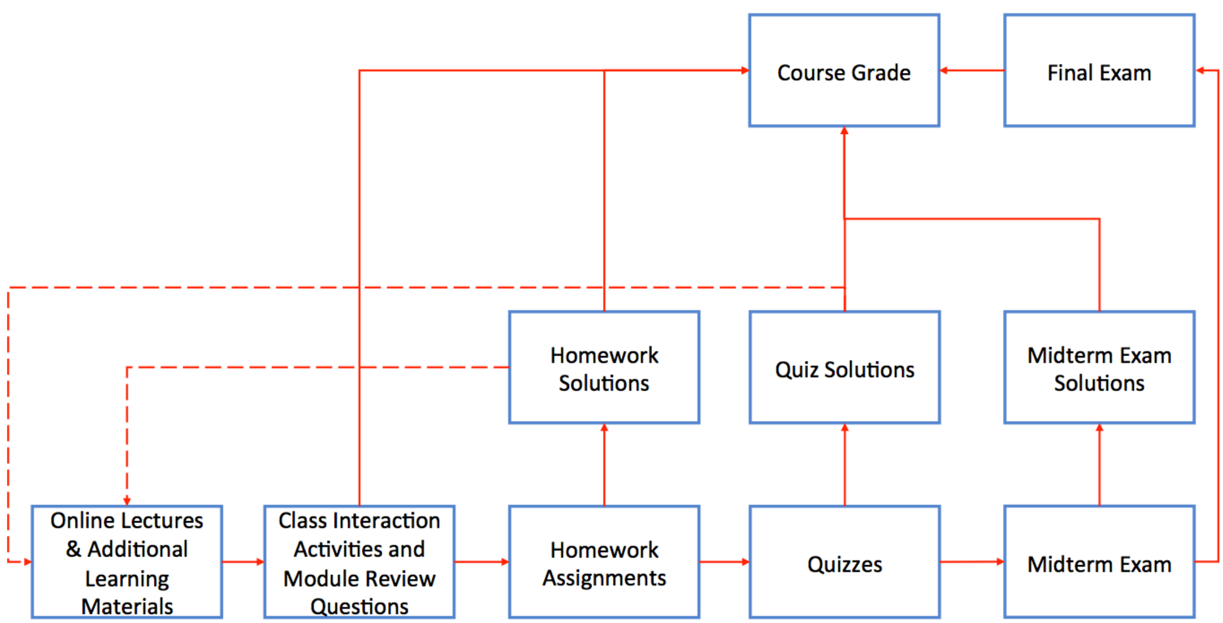

Figure 2. Overview of Learning Loop for Applied Fluid Mechanics Course (Online)

The online setting of the Applied Fluid Mechanics course is designed to provide students with an interactive, accessible and flexible learning environment. The continuous availability of the learning materials along with the assignments and their solutions provide an accessible and flexible learning environment. New materials are introduced to students in a modular setting; where a new module becomes available every 2 weeks. Students have 2 weeks to review the learning material and complete the module assignments. This provides students the flexibility of accessing and completing the assignments anytime during that 2-week period. The interactive component of the online learning is fulfilled by class interaction activity and interactive simulations. Class interaction activity is performed through a discussion board that is designed to encourage student interaction in the course. For each module, the course instructor presents students with a discussion board question. In order for students to receive full credit for the discussion board participation, they need to answer the professor's question by posting on the discussion board.

The interactive simulations are developed to aid the theoretical concepts covered in the course. The Applied Fluid Mechanics course covers a vast array of important concepts such as: viscometers, manometers, buoyancy, Bernoulli's Equation. One of the challenges for students is to visualize these concepts. As an example; seeing how a falling ball viscometer works will give students a better understanding of the concept. However, sometimes just seeing how a falling ball viscometer works may not be sufficient. It is important for students to be able to interact with the visual set-up and edit settings to see their effect on the outcome. This is only possible through a simulation-based component. The simulation-based component for the Applied Fluid Mechanics course is designed by using MIT's Scratch platform. "Scratch is developed by the Lifelong Kindergarten Group at the MIT Media Lab. See http://scratch.mit.edu" [24]. In the pilot implementation of the interactive simulations, three simulations have been developed and implemented to the course, followed by an assessment of student learning and student experience [25, 26].

Although the material covered during the in-class and online settings of the course are same, the methodologies and the learning technologies that are followed are different, so that the best learning environment can be provided to students. A comparison of in-class and online settings of the course grading is provided in Table 1.

Table 1. A Comparison of In-Class and Online Settings of the Applied Fluid Mechanics Course

In-Class setting (Textbook required)		**Online setting (Textbook required)**	
Course components	**Assessment**	**Course components**	**Assessment**
10 Homework Assignments	30%	7 Homework Assignments	15%
2 Quizzes	20%	7 Quizzes	15%
1 Mid-Term Exam	20%	7 Class Interaction Activity	10%
1 Final Exam	30%	7 Module Review Questions	10%
		1 Mid-Term Exam	20%
		1 Final Exam	30%
Total	100%	Total	Total 100%

Applied Thermodynamics Course

This course lays the groundwork for the student's future studies in the area of thermal design, encompassing the fields of power, heating, air conditioning, and refrigeration. Topics covered include basics such as the first and second laws of thermodynamics and equations of state for gases and vapors. Building on this foundation, thermodynamic processes and cycles will be introduced, including the Carnot, and Vapor Compression refrigeration cycles. Thermal equipment such as boilers, turbines, evaporators, condensers, compressors and heat exchangers will be analyzed.

The textbook used in this course is Thermodynamics: An Engineering Approach, 8th Edition by Cengel and Boles [27]. The course also requires the use of a third party web based assignment and assessment platform, "Connect" supported by the publisher, McGraw-Hill. Ten chapters were selected from the textbook as the teaching materials for the course. However, since the textbook involves calculus, the lecture notes provided by the publisher are revised to include explanations of the derivation of equations as well as simplification of the areas that involve calculus.

In-Class Setting Course Components for Applied Thermodynamics

In the traditional in-class setting, lecture notes, problem-solving examples, discussions, 9 reading assignments, 9 quizzes, 1 mid-term, and 1 final exam are provided as teaching materials to educate and assess students. Lecture notes and problem solving examples are presented to students through a writing board during the class hours. The materials are also available to students on Blackboard for reviewing. Question based reading assignments created by the publisher for each chapter are given to students through Connect. Students will read the specific sections of the chapters assigned by the instructor before or after class hours. The reading assignments are clearly guided by Connect and it's e-book. Students will have a better understanding of the course materials after completing the reading assignments because they will learn the materials twice, one by reading the e-book in Connect and the other by listening to the instructor during the class time.

The in-class setting also includes ungraded class discussions. The instructor will ask questions to the class as explaining example problems and course materials. Students are allowed to discuss with each other for course questions. Although students in this setting will have an opportunity to communicate and learn the materials in a less formal learning environment, the response rate in class discussions is relatively low. One reason is that students maybe occupied by class note taking and do not have the time to response. Another reason is that they maybe still digesting the information presented to them and are not prepared to the respond to the questions.

The assessment of the continuous learning is conducted through reading assignments, weekly quizzes, a midterm exam, and a final exam. Reading assignments are delivered to students with due days. Quizzes and exams are conducted during the class hours. An overview of the learning loop for the in-class setting of the course is shown in Figure 3.

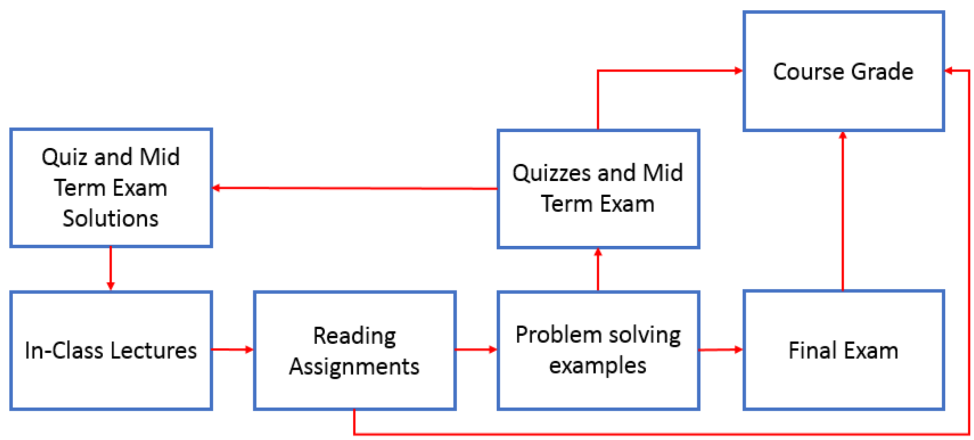

Figure 3. Overview of Learning Loop for Applied Thermodynamics Course (In-Class)

Online Setting Course Components for Applied Thermodynamics

In the online setting, the teaching materials include lecture notes, problem-solving examples, discussions, 9 reading assignments, 9 homework assignments, 1 mid-term, and 1 final exams. Unlike the in-class setting, this setting does not include quizzes. They are replaced by homework assignments. The difference between homework assignments and quizzes in the online setting is that the homework assignments have more questions and allow for longer completion period. The instructor wants the students to have more time to work on the questions and learn from the assignments.

In an effort to extend the learning experience through homework assignments, the online setting also includes ungraded discussions that mainly focus on the assignments. Students who have difficulties solving the questions can post their comments on the discussion board. This arrangement will encourage the students to participate and contribute to the discussions when they face problems in the assignments. The discussion board is restricted to explanation only.

The instructor will monitor and guide the discussion board to prevent students from providing answers of the questions directly in the comments and to correct students' comments if they are misleading. Students who can explain the method of solving the question will understand the topic very well. Students who do not understand the questions will learn how to work with others in troubleshooting the questions.

Lecture notes and problem-solving examples in this setting are presented to students via PowerPoint slides, short video clips, and Youtube [28] videos through Blackboard. Solutions of the homework assignments and exams are also presented to students by short video clips and Connect step-by-step solutions. The videos used in this course are not recorded directly from the in-class lecture. They are prepared independently targeting important sections of the chapters. The advantage of using short video clips and Youtube [28] videos to explain the lecture notes and examples is that important sections of each chapter are clearly listed and sorted by the videos. Students will know exactly what needs to be learned. They can quickly locate a section when they want to revisit the section. For example, students in the in-class setting often have difficulty memorizing the techniques of using steam tables because the students only have one or two lectures for this topic. However, with online videos, student can watch the videos of the topic as many times as they need until they understand the concept of the topic.

In addition, due to the limited in-class contact hours, very few detailed problem-solving examples and solutions of the assignments can be presented to students. Although students can study the fully explained problem-solving examples from the textbook, details can be misinterpreted if the examples are not properly guided by the instructor. Therefore, the online setting in this course allows students to learn more numbers of problem-solving examples through short video clips. Table 2 shows the comparison of in-class and online settings of the Applied Thermodynamics course. An overview of the learning loop for the in-class setting of the course is shown in Figure 4.

Table 2. A Comparison of In-Class and Online Setting of the Applied Thermodynamics Course

In-Class setting (Textbook required)		**Online setting (Textbook required)**	
Course components	**Assessment**	**Course components**	**Assessment**
9 Reading Assignments	15%	9 Reading Assignments	15%
9 Quizzes	55%	9 Homework Assignments	55%
1 Mid-Term Exam	15%	1 Mid-Term Exam	15%
1 Final Exam	15%	1 Final Exam	15%
	Total 100%		Total 100%

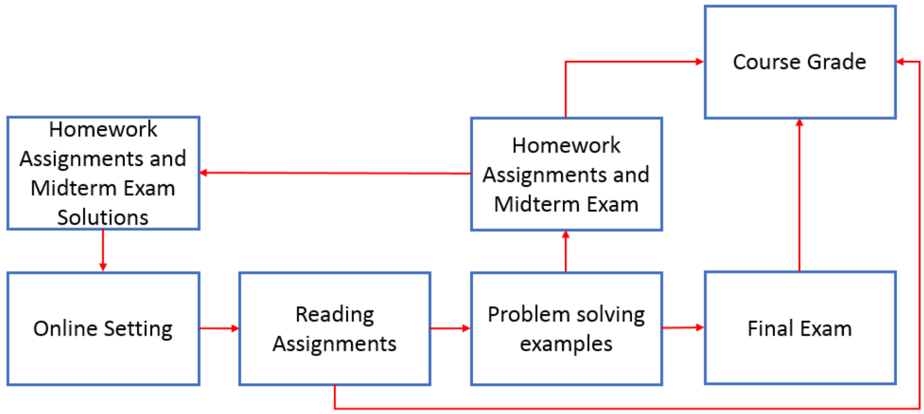

Figure 4. Overview of Learning Loop for Applied Thermodynamics Course (Online)

Conclusions and Future Work

This paper provided an overview of the in-class and online offerings of the applied thermo-fluid courses as well as methods to develop these courses online in the Mechanical Engineering Technology Department at Farmingdale State College. The set-up and the materials conveyed in the traditional in-class setting versus the online setting have been discussed. While the traditional in-class setting of the course has the advantages of direct face-to-face interaction with students, it has shortcomings in accessibility and availability to the students after the class hours. Instructors increased the accessibility and availability of the course material by sharing their lecture slides, notes, in-class examples online via course page in Blackboard. The online offering of the thermo-fluid courses provided 24/7 accessibility and availability to the students. The instructors employed Youtube videos, class interaction questions, virtual interactive simulations and discussion boards to provide students a continuous learning process where they have access to the course materials anytime. Assessment of the courses in both settings will be conducted in the near future.

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