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Implementation of MyOpenMath in Chemical Engineering Instruction

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Abstract

Often when teaching large classes it is desired to have an automated online grading system for homework and/or tests, and to have the option of giving each student a different set of parameter values so that each student has a unique problem set. While some textbooks have online platforms with question databanks for that purpose, many textbooks do not have an accompanying online system. The textbooks that have the online question and grading system are frequently expensive for students and limited to databank questions. Therefore, it is desired to use a low cost open educational resource (OER) that can be adapted to the needs of each course. One such OER is MyOpenMath, a mathematics based online tool that integrates into common learning management systems and is free for both faculty and students. In this paper we discuss how this tool is currently implemented in a senior capstone design course and a unit operations laboratory in chemical engineering. This presentation includes characteristics of MyOpenMath, benefits for instructors, available instructor training, and benefits over using current quizzes in the Canvas LMS. Not limited to chemical engineering courses, MyOpenMath is applicable to any equation based course. This paper focuses on the faculty perspective of using MyOpenMath in existing core courses.

Introduction

MyOpenMath (MOM) is a web based platform built on the IMathAS (Internet Mathematics Assessment System) [1] that is accessed through the website www.myopenmath.com [2]. Originally developed for mathematics courses, it includes an automated grading system that is applicable to any equation based course. MOM may be used to deliver homework, practice problems, tests, and/or an entire course. This software is managed by the non-profit organization MyOpenMath [3], and is currently a free for students and instructors. It has the flexibility to be used as its own learning management system (LMS), or be linked to existing college and university LMS platforms including Blackboard, Canvas, D2L Brightspace, and Moodle through standard Learning Tools Interoperability (LTI) protocols.

There are a number of advantages to integrating MOM into an LMS platform. At our institution, Canvas is used as the LMS. It is a relatively simple procedure to integrate MOM into a Canvas course and it only has to be done once per semester per course. Once integrated, Canvas exports the student list to MOM and can be seen in the MOM gradebook. The integration can be set up so that homework deadlines are set up in Canvas and exported to MOM. One benefit of the integration is that MOM exports the grades to the Canvas gradebook. Therefore, students and instructors can see the grades in Canvas. While only the grades are exported to Canvas, instructors can see student answers to every assessment from the MOM website.

In our department, multiple instructors incorporated MOM into courses across the curriculum from fluid mechanics and heat transfer courses at the sophomore and junior year to senior level capstone design and unit operations laboratory courses. This paper discusses two of these courses: a senior design course and a unit operations laboratory. Both of these courses generally have more 50 students enrolled in each course. Before discussing the implementation in each course, it is necessary to discuss features of MOM that are common to all courses.

General Implementation

Initially, faculty must apply for a password protected instructor account through the MOM website. MOM will verify that a person is an instructor before setting up the account that allows instructor access to the system. This verification process may take a few days, but only needs to be done once. Students do not need an MOM account if it is integrated into an existing LMS.

The MOM website contains existing math courses based on open textbooks including arithmetic, calculus, differential equations, statistics and linear algebra. An instructor account allows access to these courses; and it also allows creation of course material that may be set up for public access, or limited to private access by you and students in your course. For both courses discussed here, faculty created homework and tests are created based on an existing textbook. The platform allows instructors to set up course materials, to create question databanks, and to organize the databanks into separate folders according to topic. These question data banks can be kept private if desired.

There is a range of available resources on the MOM website for training instructors on how to set up homework sets and questions. These training resources consist of an online training course, a set of training videos, and a forum for instructors to submit questions. In addition, instructors can access the existing public courses on MOM (e.g. algebra, calculus, statistics) to see actual examples of course settings and programming.

For each question it is first necessary to specify the question type. Examples of question types include but are not limited to multiple choice, multiple answer, essay, number, matching, complex, numerical matrix, and multipart questions. For each question there are two sections to be created: 1) the Question Text, and 2) the Common Control. The Question Text provides the question text including any variable values students need to solve the problem. In the case of essay questions and numerical questions, it provides answer boxes for students to enter answers. That is, the Question Text section is where the instructor creates what the students will see when doing the problem. The Common Control contains the programming steps operative behind the Question Text. Variable values, equations, and calculations for numerical answers are set up in the Common Control section, as well as formatting for the answer boxes shown in the Question Text. This control section is also where tolerances can be set for determining whether a numerical answer is correct, and where the relative weight of each answer in a multipart problem can be set. For example, if a multipart problem has 3 answers, the control section can be used to set the percentage of the problem points assigned to each answer. This weighting could be set as 25%, 30%, 45%, or set as 25%, 50%, 25%. This provides the instructor control over the partial credit given for the question. Note that faculty can preview the assessment on MOM before assigning it to the students. This allows instructors to determine if each question is programmed correctly.

Senior Design (Faculty A)

Motivation for using MyOpenMath in Senior Design: Motivation for using an automated grading system in senior design is due to: the goal of returning grading homework and tests to the students in a timely manner, and preventing cheating on online tests. This author typically co-teaches the process economics material in approximately 3 weeks of the fall semester senior design course, in which two homework sets are assigned and a test is given during the 3 week session. Typically this faculty member does not have a TA for grading process economics, and

is concurrently teaching a full semester course. Given that the design course enrollment in recent years varied between 57 and 106 students, it can be challenging to grade the design homework and test in a timely manner. Because the textbook did not have a companion website that provided problems that could be assigned to the students, it was desired to find an automated grading solution.

During the pandemic in the 2020 fall semester, most courses were taught online and Canvas quizzes were used for tests. There were concerns about cheating on the online tests. Ideally, the goal was to develop online tests that allowed for each student to have a unique set of variable values on the test problems to reduce cheating, and to allow students to enter intermediate values in a multipart problem. The concern with only using the final answer from a multi-part problem was that there was no partial credit on the problem. While Canvas quizzes allow for randomized variables, they do not allow for multi-part problems. Therefore, the only way to have each student have a unique set of variable values and be able to report intermediate problem values was to create a separate test in Canvas for each student. In contrast, MOM allows for multipart numerical problems with randomized variables.

Homework Implementation: Starting in 2021, both homework sets were set up in MyOpenMath. The process economics section of the senior design course mainly uses equations and cost data from tables in the textbook appendix. This is a good fit for a numerical MOM question. Each numerical answer question consists of two parts: 1) the question text, and 2) the control program. In estimating the cost of an equipment unit (e.g. heat exchanger) it is necessary to use a cost equation with variables obtained from a textbook table to obtain costs in 2001 dollars. An example problem is shown in Figure 1 for a multipart problem where there are 13 answer boxes. Note that there are answer boxes for constants obtained from tables (K_1, K_2, K_3, C_1, C_2, C_3, B_1, B_2, and F_M) as well as for calculated results (purchased equipment cost C_P^0, F_P, C_{BM}, and current C_{BM}). Therefore, students received partial credit for correctly reading constants from tables, as well as for the calculations. Note that the bare module cost (C_{BM}) calculation uses the purchased equipment cost C_P^0, the constants B_1 and B_2, the material factor F_M, and the pressure factor F_P according to the equation:

$$C_{BM} = C_P^0 (B_1 + B_2 F_P F_M) \quad [1]$$

Therefore reporting C_P^0, B_1, B_2, F_M, and F_P allows for partial credit to be given for intermediate answers.

One convenient feature of MOM is that it is possible to retrieve a student answer and then use it for subsequent calculations. For example, the student may have incorrectly calculated the pressure factor F_P. The program can be set to mark the F_P answer as incorrect, but then use that incorrect answer in subsequent calculations. This allows the program to determine if the student understands the procedure, but does not count off for both C_{BM} and F_P when the error in F_P is the only source of error in the C_{BM} calculation. That is, the program does not count off for two incorrect answers when one incorrect answer causes another incorrect answer. Retrieving the student answer is optional and is at the discretion of the instructor when setting up the problem.

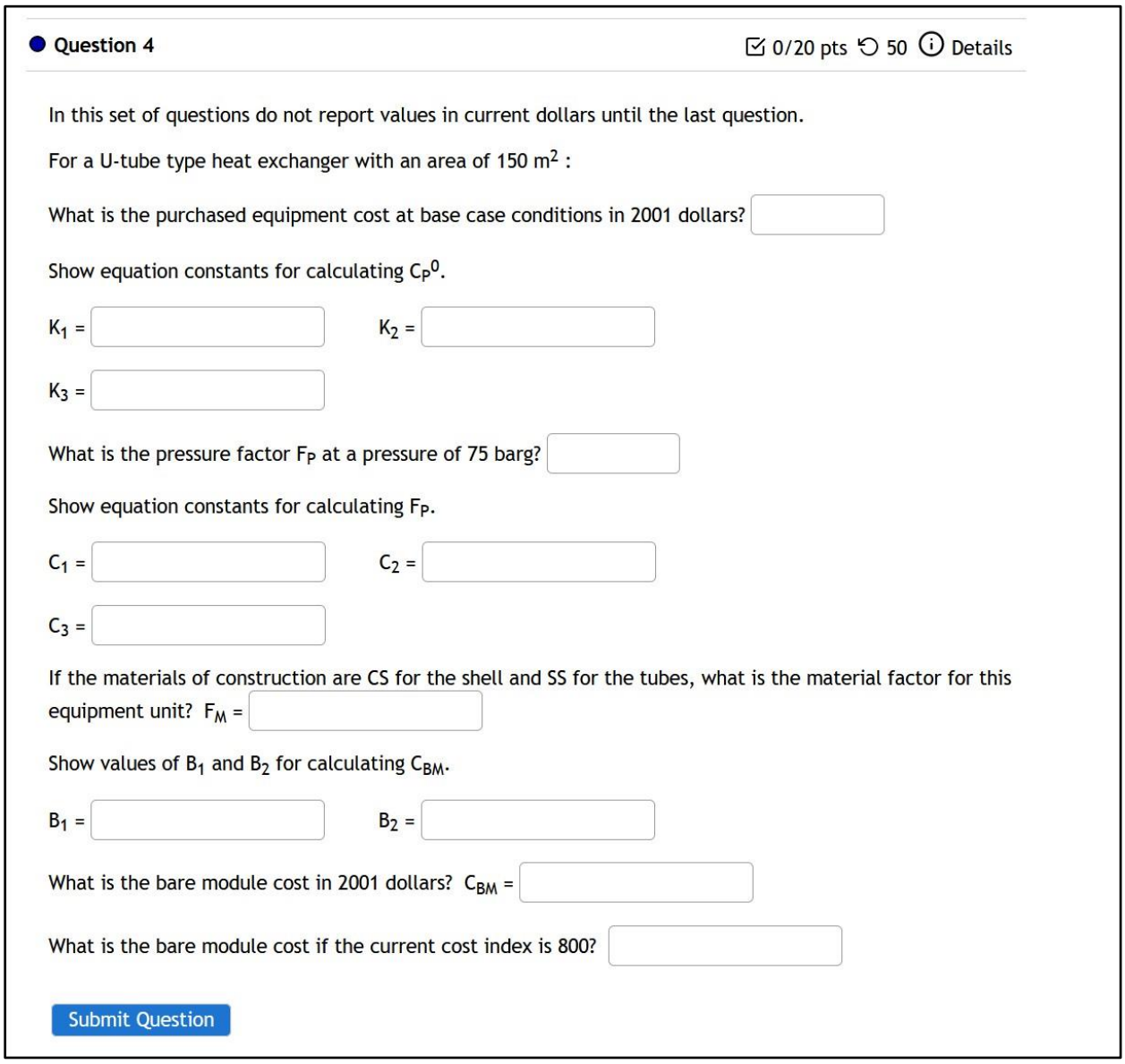

Figure 1. Example of heat exchanger cost question.

Figure 1 illustrates the student view of a question where the problem is worth a total of 20 points as shown in the upper right hand corner. In this case the student has 50 attempts to get the answers correct, where the number of allowed attempts is set by the instructor.

In the capstone design course, MOM is integrated into Canvas so that the students can access the MOM assignments directly through Canvas without creating a MOM account. This integration allows the assessment grades to be directly exported to Canvas.

Test Implementation: In 2021 and 2022 the senior design test was administered using MOM. Tests problems were set up in the same manner as for the homework. In this class, every student had the same variable values for the homework problems, but variables were randomized for the test problems to reduce cheating. MOM allows instructors to set the minimum and maximum values for each randomized variable as well as the step size. For example, a variable can be set to range in value from 5 to 100 in increments of 5. Note that students were assigned homework using MOM through Canvas to familiarize them with the platform before the test. The students were also notified before the test that the test would be through Canvas using MOM. One

limitation of MOM is that the instructor cannot see each student's work, but only the answers submitted. Therefore, students were instructed to turn in their written work for partial credit.

Used in this way, MOM pre-grades the test based on answers alone. Because the instructor has a student's written work and can look at each student's assessment in MOM, the instructor can either check all of the written work, or focus only on the incorrect answers to determine if the student deserves more partial credit. For example, the student may be using the correct equations with the correct substitutions, but makes a math error during calculations. An automated grading system cannot distinguish between a student who makes a simple math error and one who does not know the correct approach for the problem. While MOM shows the grades on each part of the problem as programmed, it allows the instructor to edit the grade as needed.

For this class, tests through MOM were only done in 2021 and 2022. The instructor discovered that students were preoccupied with determining whether or not they had the correct answer during the test. Although MOM was set up to not show the students whether or not their answers were correct, some students were looking up the transferred grades in Canvas during the test. To prevent this in the future, the instructor decided not to use MOM on tests for face to face classes.

Faculty Perception of MOM: For faculty, there is a learning curve for using MOM, but this is not a high learning curve if the instructor is already familiar with computer programming. One of the best ways to learn how to set up MOM code is to look at an example question first. Because instructors have access to existing publically available math courses on MOM, there are many example questions available. One primary benefit for faculty is that using MOM saves time grading, particularly for high enrollment classes.

Setting up a problem on MOM is easier the second time it is done. Note that separate question databanks can be created for different courses, and the questions can be reused or edited in subsequent semesters. This is very useful for the instructor, particularly after the first year. In senior design, it was often desired to create a new cost estimation problem similar to an existing problem. Having a similar existing problem allowed the instructor to duplicate the existing problem, and then edit the duplicate to create a new problem. Editing an existing problem was much faster than starting programming from the beginning, particularly for multipart problems.

For students, there was instantaneous results on grading. In previous semesters with higher enrollments, it was difficult to grade homework before the test even though homework solutions were provided to the students. Previous complaints about slow homework grading disappeared, and there were few or no complaints from students about using MOM.

Students liked that they had multiple attempts on homework. Each assignment was graded on a 100 point basis. Prior to using MOM, average class grades on the two homework assignments ranged from 70 to 89 based on data from 2018 and 2019. From 2021 to 2024 average class grades on the two homework assignments ranged from 92 to 98. In both cases the averages are limited to the students who turned in the homework. Because of the instant feedback, students worked to correct their answers and spent more time on the homework problems.

One question is how MOM usage affected test scores. In 2018 and 2019 the average test scores were around 88, in 2021 and 2022 the average grades were about 80, and in 2024, the average test grades were about 90. The test scores in 2021 and 2022 most likely were lower because the students spent time looking up their grade in Canvas during the test and therefore spent less time

on the actual test. Note that after 2020 all the homework was on MOM, so the only difference in these years were whether or not the test was administered through MOM.

Unit Operations Laboratory (Faculty B)

Motivation for using MyOpenMath in Unit Operations Laboratories

Similar to factors motivating use of MOM in senior capstone design, the ability to assign multifaceted problems tied directly to the Unit Operations experiments wherein each MOM generates a unique set of given conditions for each student is a very attractive feature. Also, the immediate feedback of graded responses is valuable for enabling both students and instructor to assess student understanding of the experiment performed. And, as laboratory reports for each experiment have traditionally been team-written, the use of MOM allows assessment of individual student performance beyond the assessment of individual contributions to the team assignments.

MOM Assignments tied to Unit Operations laboratory experiments

Our institution requires two Unit Operations laboratory courses: the first focused on fluid mechanics, heat transfer and thermodynamics and the second focused primarily on reactor design and kinetics and separations. For each course, teams of 4-6 students operate each of five assigned experiments in biweekly sessions. Data analysis and report writing is accomplished between the active laboratory sessions.

Beginning in 2022, we began introducing MOM problems as assignments accompanying each experiment. Figure 2 illustrates a heat transfer/energy balance problem associated with one of our experiments.

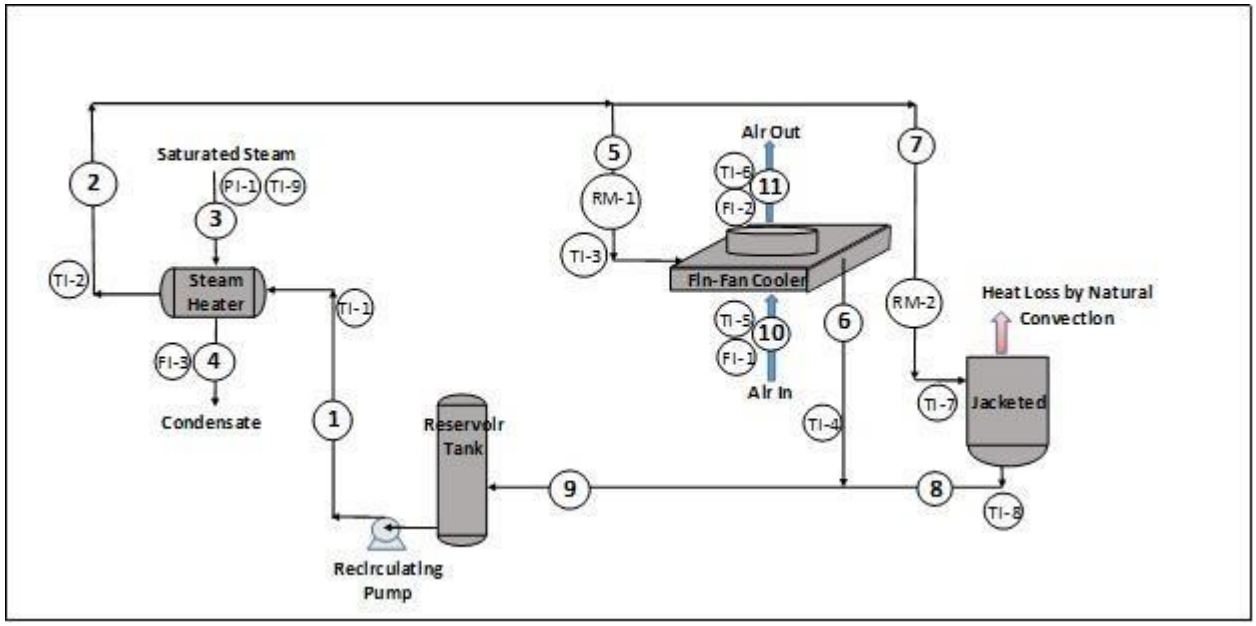

Figure 2. Example heat transfer/energy balance problem for unit operations laboratory.

Programming in the *Common Control* window of MOM allows each student to receive unique information for EACH ATTEMPT. Coupled with diminishing point values for correct answers

for each attempt, an incentive is provided for students to give due diligence to accurately interpreting and calculating answers.

Example questions for one experiment are shown below in Figures 3a and 3b.

For the system shown above:

- **Entire system is at Steady State**
- **Instrument Locations shown as: TI (temp); FI (flow); PI (psia); RM (rotameter)**
- **Water cp = 1.0 btu/lb-F ; Air cp = 0.241 btu/lb-F**
- **Fin-Fan face velocity = 723 ft/min**

Use the Steam Tables to determine the following:

- **What is the Saturated Steam Enthalpy, btu/lb?**
- **What is the Stream 4 Condensate Enthalpy, btu/lb?**
- **What is the Latent Heat of Vaporization, Hvap, btu/lb?**

Figure 3a. Part 1 of questions based on given data and Figure 2.

Fill in the stream table answer boxes

Stream	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Flow (lbs/hr)											
(gpm)					**5.6**		**6**				
Temperature (F)	**119**	**136**	**238**		**135**		**135**	**129**	**122**	**70**	
Pressure (psia)											
Density (lbs/ft3)					**61.45**						

Calculate and Enter the following Heat Duties

(REMEMBER TO ENTER THE CORRECT SIGN (HEAT ADDED=positive, HEAT REMOVED=negative)

- **Shell/Tube exchanger water-side duty, btu/hr**
- **Fin-Fan exchanger water-side duty, btu/hr**
- **Jacketed exchanger water-side duty, btu/hr**
- **Reservoir Tank water-side duty, btu/hr**
- **Uninsulated piping/equipment water-side duty, btu/hr**

Shell/Tube exchanger

- **The duty of this exchanger adheres to the standard heat transfer equation**
- **$Q = Uo * Ao * \Delta T_{lm}$; where ΔT_{lm} is the log mean temperature difference, F The total exchanger outside tube area, Ao, is 50.25 ft2**
- **What is the ΔT_{lm}, F?**
- **What is the overall heat transfer coefficient, Uo, btu/hr-ft2-F?**

Figure 3b. Part 2 of questions based on given data and Figure 2.

Similar to the problem illustrated above, MOM problems have been developed and tested for our fluids experiments and other heat transfer experiments. Problem design is underway for the remaining experiments used in both Unit Operations laboratory courses.

Additional work is in development for our integrated chemical and petroleum engineering freshman year project-based experimentation.

Concluding Remarks

Both instructors plan to expand their use of MOM both in courses where MOM is currently used and in courses where it has not been used. The use of MOM question databanks is still under development in multiple courses.

Comparison to Canvas quizzes: MOM has all of the benefits of Canvas quizzes, but adds additional useful features. Both platforms are flexible as to question types, allow instructors to set points for each problem, have automated grading of homework/tests, allow randomized variables, and can report the grades to the Canvas gradebook. Distinguishing features of MOM consist of being able to set up multipart problems with randomized parameters, being able to weight points for each of the answers in a multipart problem, and being able to read a student's numerical answer and use it in subsequent calculations in the same problem.

Benefits to Faculty: Benefits to faculty include reduction of time spent grading due to homework being graded instantly, option to create question databanks by course for reuse in later semesters, option to make question databanks private, ability to give partial credit in multipart problem.

Benefits to Students: One benefit of instant feedback to students with multiple attempts on homework is that many students are more engaged with the homework and will rework the homework to get a higher or perfect score. Other benefits include instant feedback through automated grading.

The use of MOM in the Unit Operations laboratory courses has enhanced the "granularity" of student assessment. Student comments have ranged from very positive to mildly negative. Among those students who often naturally lead their teams in writing ability and technical understanding, comments are mostly positive—indicating a perception that MOM problems helps to differentiate among student performance more clearly than the written technical reports along. Negative comments are generally associated with those students who feel the individualized assessments add "stress" to the course, but with associated comments that these assignments HAVE improved their focus on the experimentation and understanding of the operations being studied.

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