Opportunistic Engineering – A Student Project That Keeps on Giving

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Abstract

Last year we authored a paper describing a unique opportunity to develop a summer internship program at Mercer University. This successful program teamed small groups of students with faculty to address either a research topic or engineering project. The name of this internship program is the "Mercer Summer Engineering Experience, or MeSEE. In this paper we describe the MeSEE project we directed with four summer intern students.

The problem we were addressing was improving the registration process for our freshmen engineering students. Specifically, we were trying to address the challenge of creating viable Fall schedules for our Freshmen from the thousands of possible schedules. In addition, we were also attempting to obtain the best schedules for our students while competing against other schools to fill common classes.

This paper describes forming the team of students, the solution approach, and the final engineered product. What took two and half days of frustrating work for two schedulers for the Fall 2014 freshman class, took approximately three hours for four schedulers when registering the Fall 2015 class. The Fall 2016 registration process repeated the performance of 2015.

Keywords

Summer Internships, Engineering Projects, Scheduling, and Registration.

Introduction

Summer research opportunities for undergraduate students are used to empower research advancement for faculty and offer research experiences for students, preparing them for industry, medical research and academia. To encourage these activities, the National Science Foundation (NSF) makes extensive investments for undergraduate students to perform academic research in engineering and science through its Research Experience for Undergraduates (REU) program [Economy et al.[4]]. Gilmore et al.[6] observed the assessment of research skills to investigate associations between undergraduate research experiences and research skill performance in graduate school, and concluded that it was highly beneficial both for students and faculties. Delatte[4] experienced a summer research program for undergraduates in structural engineering, funded by the National Science Foundation, operated at the University of Alabama at Birmingham. The program was intended to provide students interested in graduate studies with an introduction to research methods, and to provide students theoretical foundation of engineering practice. Nambisan et al.[7] summarized a pilot student internship program developed jointly by the Iowa Department of Transportation (DOT) and the Institute for Transportation at

Iowa State University, in which interns valued opportunities to work in professional settings, interactions with other professionals and practitioners, and opportunities to understand real-world application of their course work.

This paper describes a successful student summer research project resulting in a tool that improves the freshmen registration process for Mercer University's School of Engineering. The tool is an Excel-based application which generates all feasible freshmen schedules and ranks these schedules based on student defined criteria. This is not the first time students have helped us develop useful tools. Biswas et al.[2] and Biswas and Lin[3] describe a project funded by the US department of education to create a student homework repository for homework submission in STEM courses. The tool assigned homework to be graded anonymously by other peer students with the intent to educate students by means of observing their own mistakes.

The program which provided the structure for this summer engineering project is presented in Baker et al.[1]. In this paper we describe a self-funded summer undergraduate research program at Mercer University where teams of engineering students work with faculty on research or design projects. This program, known as the Mercer Summer Engineering Experience or MeSEE, was launched during the 2015 summer term. Ninety five students and twelve faculties participated during this inaugural year. These students dedicated anywhere from 20 to 40 hours a week over a 10 week period on their projects. The results of the program were widely hailed as a success by both the participating students and faculty.

To describe this project, we begin with an illustration of the freshman registration process at Mercer University and the challenges this process presents. Then the MeSEE program is described, beginning with the recruitment of the student team, followed by the problem statement presented to this team, a description of the tool the team built and how the tool is implemented. The final section represents the results of using the tool during the 2015 and 2016 freshmen registration.

Mercer Freshman Registration Process

Each year during May, incoming freshmen are registered by academic advisors for their upcoming fall semester. For each of the last two years the four schools/colleges at Mercer, which contain freshmen, gathered in a single room to register these students. The purpose of this gathering was to help resolve common problems as they occurred, such as the need to add a section of Calculus, or inform everyone a particular section of Psychology can only serve Liberal Arts students, etc.

Table 1: 2014 Freshmen Registration Ration

School	Scheduling Reps	Incoming Freshmen*	Scheduler to Freshmen Ratio
Liberal Arts	12	450	37.5
Engineering	2	204	102
Business	3	90	30
Music	2	20	10

*Approximate enrollments

In 2014, the school of Engineering arrived at the session with two representatives to create freshmen schedules. Upon arrival we found that the College of Liberal Arts had about twelve schedulers, the Business school had three schedulers, and the School of Music had two. We immediately knew we were in trouble especially considering the distribution of students. Table 1 highlights this situation.

We immediately began creating schedules for our Engineering freshmen. To create schedules, in the campus management system, courses are added one by one for an individual student. If there is a conflict of times between an existing scheduled course and the section you are attempting to add, the system informs you. To help avoid selecting a class section that contains a timing conflict, we created about a dozen course templates beforehand with feasible schedules. This tends to work well until a class section fills. Unfortunately, while the system lists the other available sections, only the section number appears, not the time. Thus, finding an alternative schedule at this point is non-trivial.

A second problem was that after several hours of scheduling, our dozen or so templates had become obsolete. At least one class section from each of the templates had filled. Also, if a new section of a class had been created during this registration session, none of our templates contained this section. With many of the sections no longer available, creating a feasible schedule from the remaining sections became non-trivial.

We found that if all goes well using one of the templates a student can be registered for a full 14-credit fall schedule in about 5 minutes. If a section fills and an alternative schedule must be produced, it could take 10 minutes or more. Ultimately if took almost 2.5 days for the two schedulers to produce schedules for the 204 freshmen engineers.

2015 MeSEE Freshmen Scheduling Project

To address the problems encountered during the 2014 freshmen registration process, we took advantage of the opportunity to participate in the MeSEE program and create a project to improve this process.

Team Formation

The first step was to recruit a team of students. This project required the following skills: system design, computer programming, scheduling, and process improvement. We therefore recruited industrial engineering students. After about a month of inquiries, we were able to recruit four rising seniors, 3 of which were pursuing industrial engineering degrees and 1 who was pursuing an industrial management degree.

Problem Statement

We approached this project by giving the students a set of guidelines, but also gave them significant liberty to provide suggestions for improvement. The guidelines included the following:

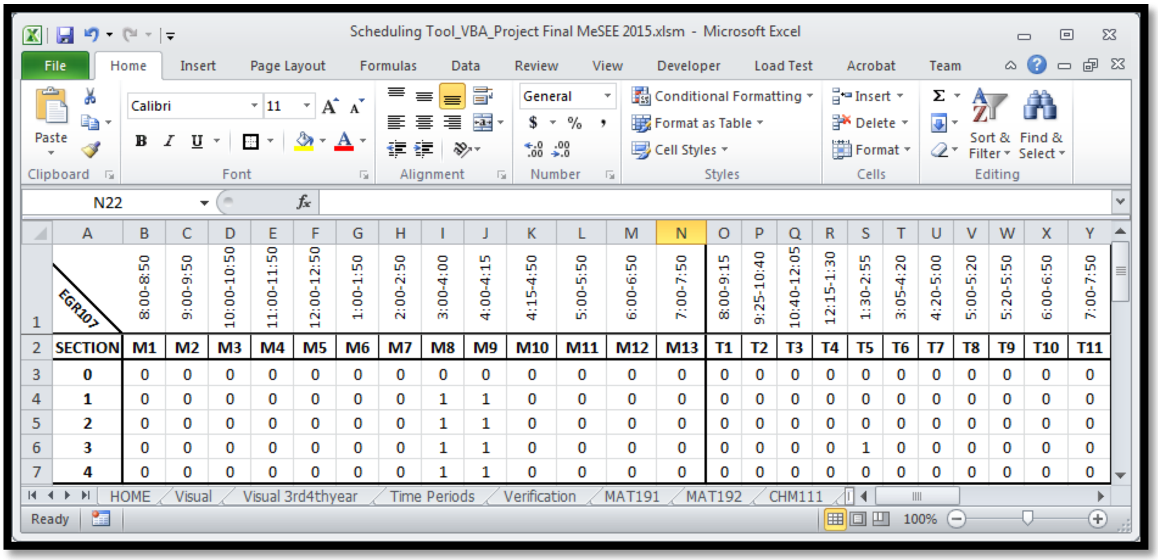
- Develop a software tool that could be configured by a user / non-programmer.
- Develop the tool in Excel and VBA.
- The tool should at a minimum produce all the feasible combinations of schedules for a selected set of courses. Feasible combinations consist of sections for the selected courses that have no time conflicts. The courses included:
    - CHM 111 – General Chemistry
    - MAT 191 – Calculus I
    - EGR 107 – Introduction to Engineering
    - EGR 126 – Programming for Engineers
    - TCO 141 – Intro to Professional Communication
    - REL 130 – New Testament
    - REL 150 – Old Testament
    - UNV 101 – Freshmen Experience

- Schedules should be ranked based on the student's perception of what makes a desirable schedule, such as a break for lunch, courses that start after 9am, courses that finish before 6pm, etc.

- Provide a user's manual for the tool.

Solution Approach – Scheduling Tool

To produce all feasible combinations of schedules, the students first had to design a means of capturing a course section's "time of day" footprint. They did so by segmenting a day into a series of time slots based on start times and finish times throughout the day. They then created a simple configuration worksheet in Excel in which the user inserts a 1 or a 0 to indicate if the section of the class is in session or not. Figure 1 below is a partial example of when the four sections of EGR 107 meet. Figure 1 only displays Monday and Tuesday for brevity sake, while the full input worksheet includes Wednesday, Thursday and Friday. Note that all four sections of EGR 107 meet from 3:00pm till 4:15 pm on Monday, and section 3 meets on Tuesday from 1:30pm till 2:55pm (the other three sections meet at various times on Wednesday and Thursday).



EGR107	8:00-8:50	9:00-9:50	10:00-10:50	11:00-11:50	12:00-12:50	1:00-1:50	2:00-2:50	3:00-4:00	4:00-4:15	4:15-4:50	5:00-5:50	6:00-6:50	7:00-7:50	8:00-9:15	9:25-10:40	10:40-12:05	12:15-1:30	1:30-2:55	3:05-4:20	4:20-5:00	5:00-5:20	5:20-5:50	6:00-6:50	7:00-7:50
SECTION	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
4	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 1 – EGR 107 course section time of day footprint (only Monday and Tuesday displayed)

A configuration worksheet, like the one shown in Figure 1, is provided for each of the possible fall freshmen courses. Note the worksheet tabs in Figure 1 which includes configuration worksheets for MAT 191, CHM 111, UNV 101, EGR 107, EGR 126, etc.

The students then had to provide a user interface which prompts the user to select the freshmen courses for which to generate feasible schedules. To initiate this selection process, the students designed a Home page shown in Figure 2.

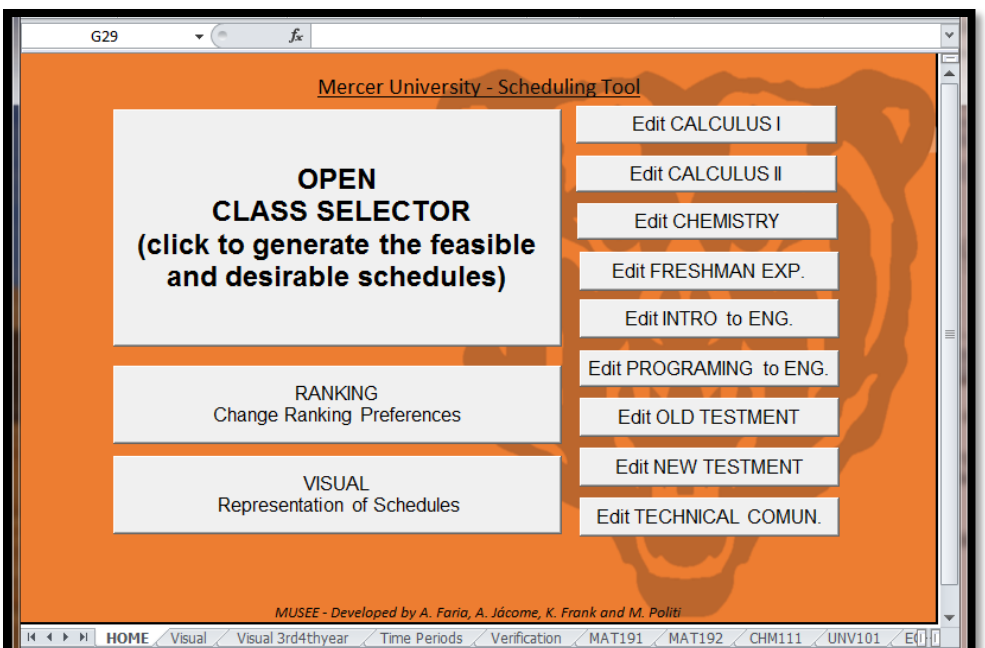


Figure 2 – Scheduling Tool Home Page

When the user clicks on the "Open Class Selector" button, the pop-up screen shown in Figure 3 appears. The pop-up requires the user to select a set of mandatory and optional courses. At the Mercer University School of Engineering, all freshmen are initially scheduled in Calculus I, General Chemistry, Freshmen Experience, and then two of four additional courses; Intro to Engineering Design, Technical Communications, Old Testament, or New Testament. Figure 3 is an example where the user wishes to produce feasible schedules for the three mandatory courses with the optional courses of EGR 107 and TCO 141.

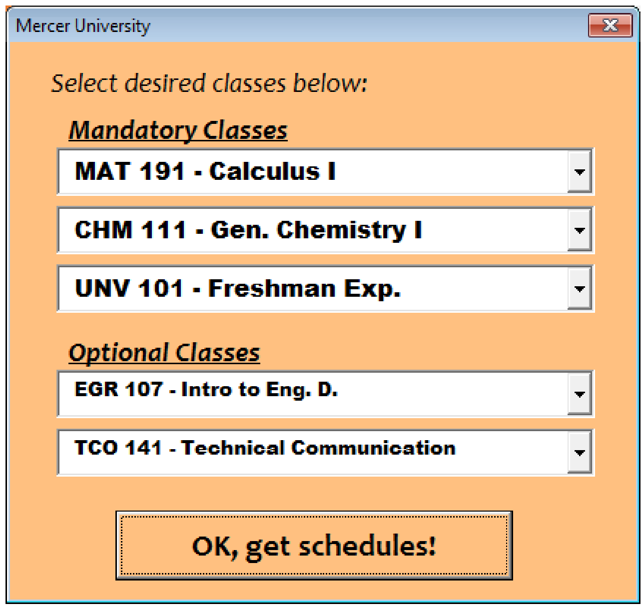
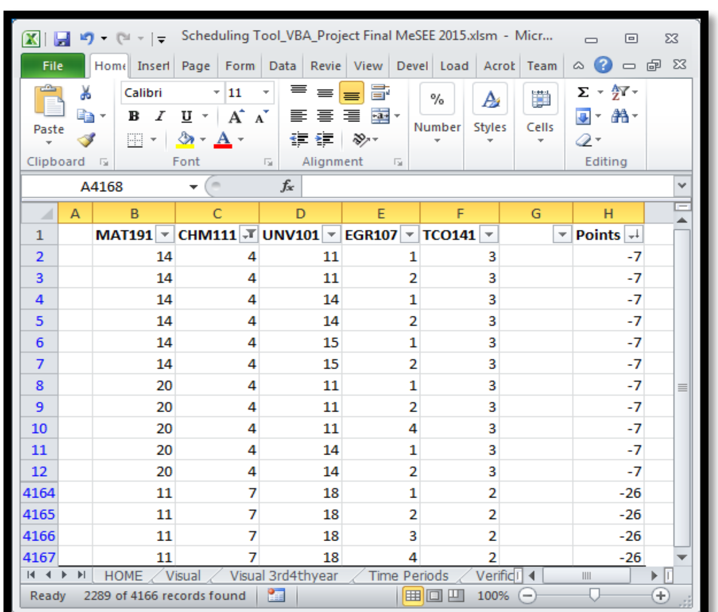


Figure 3 – Course Selection Pop-up Screen



	MAT191	CHM111	UNV101	EGR107	TCO141		Points
2	14	4	11	1	3		-7
3	14	4	11	2	3		-7
4	14	4	14	1	3		-7
5	14	4	14	2	3		-7
6	14	4	15	1	3		-7
7	14	4	15	2	3		-7
8	20	4	11	1	3		-7
9	20	4	11	2	3		-7
10	20	4	11	4	3		-7
11	20	4	14	1	3		-7
12	20	4	14	2	3		-7
4164	11	7	18	1	2		-26
4165	11	7	18	2	2		-26
4166	11	7	18	3	2		-26
4167	11	7	18	4	2		-26

Figure 4 – Partial List of Feasible Schedules Sorted by Score

Upon selecting the "OK, get schedules!" button, a worksheet is inserted into the scheduling tool displaying all the feasible schedules. Figure 4 shows the list of feasible schedule for the courses selected in Figure 3. A total of 4166 feasible schedules were generated. Figure 4 displays the first 12 feasible schedules and the last 4 feasible schedules. The rows of feasible schedule in between have been hidden for display purposes only. Columns B, C, D, E and F display the section numbers for the corresponding courses while column H display a score. The schedules are sorted in descending order from the best score to the worst score.

The students were given complete freedom to develop the scoring system for ranking schedules. The approach they chose was to assess a penalty any time a class is scheduled during a certain time window. Figure 5 shows this approach where the default penalty costs are provided on row 16. Figure 5 displays only Monday and Tuesday whereas the worksheet also includes Wednesday through Friday. The defaults show that these students were particularly adverse to having classes scheduled during the lunch hour, and were somewhat adverse to early morning or late evening classes. These weights can be easily be modified by the user.

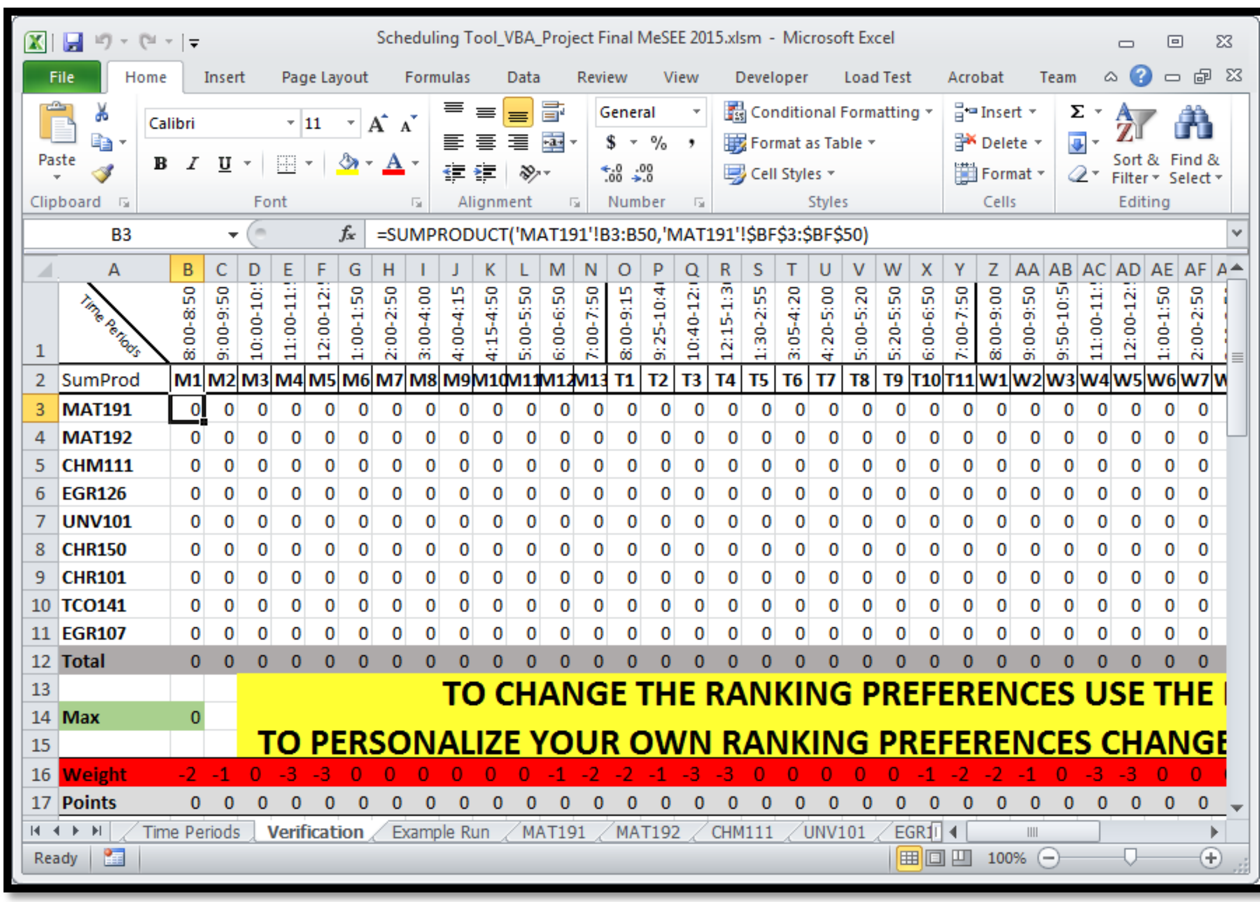


Figure 5 – Schedule Weights

To create the sorted list of feasible schedules, the students used VBA to obtain the time of day footprints for each section of the five selected courses and then enumerated all combinations. The enumeration was performed using five nested "for-loops". A course section and it's time footprint is added at each level in this nested loop. If a section is added which results in an overlap in the time footprint, then that combination of sections is abandoned. If there was no overlap in times on adding the fifth course in the inner most loop, the schedule was saved and a score was applied summing the weights for all the scheduled times. Once the entire list of feasible schedules was generated, the students took advantage of the sort and filter functions within Excel to produce the sorted list. Note, when using this nested for-loop approach, placing the courses with the largest time footprint, such as MAT 191 or CHM 111, in the outermost loops results in the most time efficient generation of schedules.

Tool Implementation

To use the tool during the registration process, the user first configures all the course section times. The user then verifies or modifies the weights. Finally the user will generate lists of feasible schedules, selecting the three mandatory courses and then several combinations of the optional courses. This Excel workbook is then brought to the registration process, not only as a listing of feasible schedules, but also to be used interactively during the registration process to eliminate schedules as class sections fill.

Excel provides a feature in which items in a list can be "filtered". This process of filtering was extremely beneficial when a class section filled and was no longer available. For example if section 10 of MAT 191 and section 12 of CHM 111 no longer had seats available, the user can use the drop down filter in row 1 of the spreadsheet to remove each of these sections from being displayed. Figure 6 shows the same list of schedules as shown in Figure 4 but with section 10 of MAT 191 and section 12 of CHM 111 filtered. This process of filtering course sections can be performed in real time as the sections fill such that only feasible schedules with available seats are displayed.

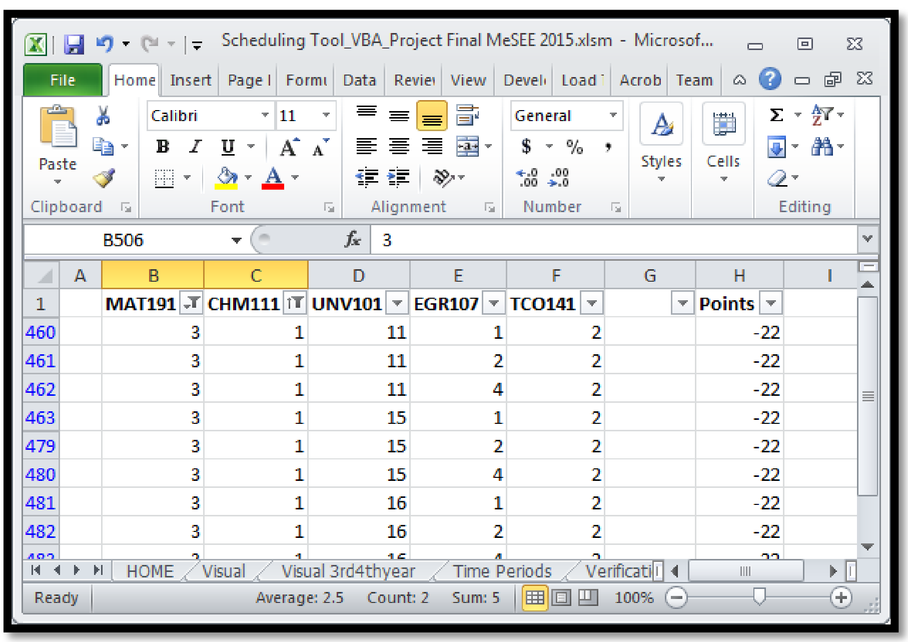


Figure 6 – List of Feasible Schedules with Section 10 of MAT 191 and Section 12 of CHM111 Removed via Excel Filter

Results

Before 2015, the registration session used to take approximately 2.5 days for two schedulers to create 180 freshmen schedules. During the 2015 registration session, engineering brought four schedulers armed with the new scheduling tool in order to register approximately 160 freshmen. The registration session began at 9:00am and by noon all 160 freshmen had schedules. None of the other schools were finished and looked like they were planning on staying the rest of the day.

The tool was again used for the 2016 freshmen class registration process and it delivered similar performance. Again four schedulers were able to register all 160 freshmen by noon where the other colleges were in the early stages of registration.

The school of engineering's Freshmen Director has been effusive in his praise of this system, citing it often in his report at our annual faculty workshop. He has also requested enhancements, such as including an optional penalty for stringing courses together with no breaks. This feature has been added and is available for the 2017 registration.

Conclusion

The student developed freshman scheduling tool has been a success. Obviously doubling the number of schedulers from 2014 to 2015 had a major impact on the reduction in registration time. The other primary factor in reducing the registration time was the scheduling tool. The scheduling tool allowed us to have instant access to viable schedules as sections filled without hunting and pecking to find those elusive sections that did not conflict. Not only did the tool reduce registration time, but also steered us to schedules which students themselves deemed "good" schedules.

In addition, the development and successful implementation and use of the scheduling tool was just one of many successful student projects made possible by mercer's Summer Engineering experience program.

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