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Work in Progress: Redesigning Curriculum to Foster Student Success

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Motivation

For years various organizations and institutions like The National Academy of Engineering [1], the National Science Foundation [2], and the American Society of Engineering Education [3], have called for curriculum reform in engineering education. On group called Big Beacon, which was formed by faculty at Olin College and Illinois Foundry for Innovation in Engineering Education developed the Big Beacon manifesto which points out that the best students of today "come to school in search of the excitement of creating cutting edge technology or helping people through engineering find something else. They find an educational system stuck in a rut." Big Beacon also notes that there are educators who "strive to overcome tis educational rut [4]." Louisiana Tech University heeded this call many years ago. The College of Engineering and Science at Louisiana Tech University has established itself as an innovator in engineering education through its pioneering first-year curriculum called Living *with* the Lab (LWTL) [5], [6]. The LWTL curriculum was featured in the paper "Integrated Engineering Curricula" written by Jeffrey Froyd and Matthew Ohland where the authors discussed various engineering programs that have taken inventive approaches to engineering education through integrated curricula efforts [7]. The LWTL curriculum has expanded to other universities across the nation. Faculty have come to visit the Louisiana Tech University campus to learn more about the LWTL curriculum. Portland State University [8], Campbell University [9], Louisiana College [10] all have adapted the curriculum to be used at their institutions. Additionally, Houston Baptist College visited Louisiana Tech University's campus in early 2018 with the intent to adapt the LWTL curriculum as the foundation of their newly announced engineering program [11].

In the paper, "The Evolution of Curricula Change Models within the Foundation Coalition" featured in the Journal of Engineering Education, the authors draw the conclusion that, "a curriculum is dynamic rather than static and that it requires on-going support if it is to not only survive but grow. [12]" This is an important conclusion to apply to curricula like LWTL. The content has been sustained over the course of its 11-year history and, as mentioned, it has grown to other universities. However, without viewing it as dynamic, the curriculum would remain unchanged and stagnant. In order for true growth to occur, the curriculum must be updated and refreshed. In the paper, "Utilizing the Engineering Design Process to Create a Framework for Curricula Design," the authors make the argument that curricula design is iterative like the engineering design process [13]. Even when you are "finished" with a design, there is always room for improvement and redesign. It is as if curriculum is a living document needing to be updated in order to be sustained. This point of view is the driving motivation for the redesign of the LWTL curriculum which will be discussed throughout this paper.

A History of the Curriculum

The LWTL content was first implemented in 2007 for all first-year engineering students at Louisiana Tech University [14]. The goal of the curriculum is to provide a student-centered approach to engineering education that incorporates engineering fundamental concepts with hands-on experiences through fabrication, programming, and design. Due to the University's unique quarter system that awards semester-credit hours, the yearlong three-course sequence elapses three quarter awarding a total of 6 credit hours, 2 credit hours each quarter. Each course consists of different key engineering concepts are taught through the combination of lectures and hand-on projects. The content focuses on student centered-learning with emphasis on engineering fundamental concepts, design, fabrication, programming, and using a microcontroller to provide a more engaging way to empower students to learn engineering. Table 1 provides a condensed summary of the LWTL curriculum content.

Table 1. Summary of LWTL content

Course	**Engineering Fundamental Concepts**	**Projects**
ENGR 120 Engineering Problem Solving I	Electricity, Conservation of Energy, Efficiency, Linear Regression Analysis	Pump Fabrication, Pump Testing and Analysis, Robotics Challenge
ENGR 121 Engineering Problem Solving II	Conservation of Energy, Conservation of Mass	Fish Tank (Control Temperature and Salinity of Water)
ENGR 122 Engineering Problem Solving III	Statics, Gears, Conservation of Energy, Engineering Economics	Open Ended Smart Product Design

Initially the curriculum was designed to be used with the Parallax BOE-Bot. The content remained generally unchanged until 2011, when the faculty decided to change the microcontroller platform to the Arduino. The decision to switch platforms was based on a few factors. One factor was due to successful efforts of the College to provide STEM outreach to area high schools. Many students were coming in with proficiency with the Parallax BOE-Bot. Additionally, the Arduino provided more functionality. Thus, changing to the Arduino allowed for advances to the projects being conducted in the classes. Also, choosing to use the Arduino required the curriculum developers to design a chassis to make the microcontroller mobile for the ENGR 120 robot challenge. This chassis construction added more fabrication opportunities for the students to experience.

When the Arduino was implemented in the curriculum in 2011, updates were made to course materials to reflect the new microcontroller. However, since that time six years ago, the course has not undergone a major update. Viewing curriculum as a living document, faculty at Louisiana Tech University have decided to rewrite and overhaul the course materials. The current iteration of the redesign is geared toward restructuring the content to more systematically foster student ability to solve complex, multi-step problems involving circuits, conservation of energy, material balance, statics and engineering economics, while also utilizing a new cost-efficient robot that was designed in-house. More focus is also being placed on soft skills like teamwork and communication. Some of the revision materials for the curriculum includes: notes that have more structure and clarity, new engaging projects that drive the fundamental concepts presented, more time built-in during class to work on projects, structure for group assessments, and a fresh set of homework questions.

Timeline of Redesign

Figures 1, 2, and 3 depict the current timeline for the curriculum redesign and plan for full implementation.

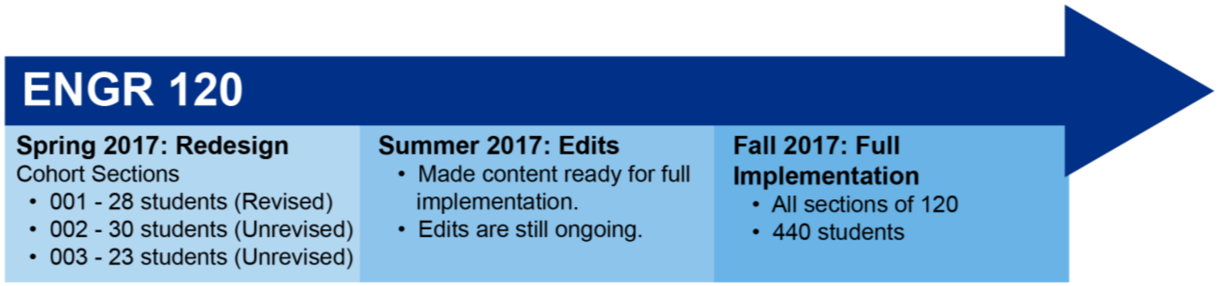

Figure 1. Redesign timeline for ENGR 120, the first course in the LWTL series.

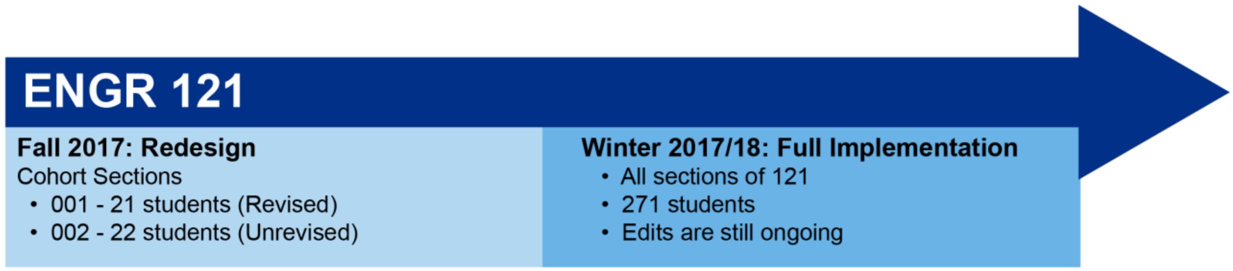

Figure 2. Redesign timeline for ENGR 121, the second course in the LWTL series.

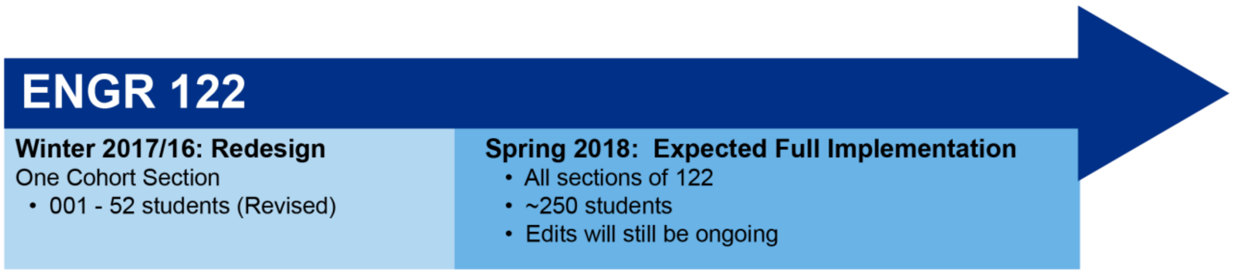

Figure 3. Redesign timeline for ENGR 122, the third course in the LWTL series.

Note in Figure 1, the quarter of the initial ENGR 120 curriculum redesign there was one section of the course that was experiencing the redesigned content as it was being created while two sections were experiencing the course without the redesigned content. Similarly, as seen in Figure 2, in the Fall of 2017 one section of ENGR 121 was experiencing the redesigned content as it was being created while one other section was experiencing the course without the redesigned content. However, this trend ended as seen in Figure 3, in the current Winter 2017/18 quarter where all sections were combined into one, where all ENGR 122 students are experiencing the redesigned content as it is being created. The cohorts of each redesigned section along with past data will be used for analysis. The number of students depicted in each cohort reflects the number of students who registered for the course. In each section there were a number of students who withdrew from the class and did not finish taking the course.

The ENGR 120 and 121 content has been fully implemented in Fall 2017 and Winter 2017/18, respectively. Data from the full implementation will also be used in analysis to understand the impact of the redesign.

Highlighting Changes Made to the Content

For each of the courses, ENGR 120, 121, and 122 the course notes are generally built using PowerPoint. A new uniform template was developed for the content that is carried throughout each of the courses. The template was strategically designed to have a clean, clutterless appearance to foster understanding and limit the amount of distracting content. All notes are being updated to use the new presentation format along with better quality pictures and images that describe content being presented. In ENGR 120 and 121 specific presentations were created to enhance the content. Additionally, material was restructured to provide a clearer and more systematic flow of topics. Revisions of presentations and restructuring of content is currently happening with the ENGR 122 course.

The content in ENGR 120 was redesigned to have more structure for the first-time students. More presentations and challenges were created to help students better understand the material. A few concepts that were originally in the curriculum were taken out and moved to another course in the sequence which allowed for more time for project work in class. Table 2 summarizes key changes for ENGR 120.

Table 2. Summary of key changes for ENGR 120

Restructured	
Soldering presentation was shifted later and adjusted to focus on soldering battery pack.	
Digital input from switches was moved earlier provided a more time to understand digital signals.	
Analog signals were moved to later in the course such that students can better comprehend the difference between digital and analog signals.	
An autonomous navigation challenge was added to help students understand libraries, user-defined function and to better prepare for the end of quarter robot challenge.	
Notes were added into more days to scaffold the regression analysis content.	
More emphasis was placed on linear regression (theory and calculations) by removing calculating power and exponential regression by hand.	
Removed piezospeaker challenge with the intent to place the challenge in ENGR 121.	
Moved up conservation of energy (pump efficiency) concept by five classes to provide more time to understand the concept. This also yielded more homework practice on the topic.	
Moved up pump fabrication by two classes which provides more time for students to work on pump project which also allows for the end of the quarter to be less congested with the robot challenge.	
Made students solder longer leads on photoresistor and complete a photoresistor navigation challenge which will help with their end of quarter robot challenge.	
Built in three days of in class time to work on robot challenge and pump project	
New Presentations	
Presentation Title	***Purpose***
Intro to Living with the Lab	Includes tips and guidelines for success with the LWTL curriculum.

What's in Your Kit	Provides images and descriptions of all items in the toolkit that each students receives.
Robot Assembly	Provides guiding instructions for the fabrication and assembly of the new cost-efficient robot that was designed in-house.
Building Circuits on the Breadboard	Guides students to build simple resistor circuits on their breadboard.
Troubleshooting Multimeters	Provides a reference for students to understand how multimeters work and troubleshoot any issues that may arise with them (example: blown fuse).
Introduction to Excel	Provides a step by step guide that introduces key functions in Excel.
SolidWorks Introduction	Provides a step by step guide that introduces SolidWorks to students.
Drawing a Barbed Fitting	Guides students through drawing difficult geometry and using the revolve tool in SolidWorks.
Using your Dial Caliper	Provides reference on how to use a dial caliper.
Practice Problems	Created practice problem bank to provide multiple problems that will help students prepare for midterm and final exams.

The structure of the ENGR 121 content was significantly changed. The main project which lasts all quarter long requires the students to build a fishtank-like platform that autonomously controls the salinity and temperature of water in a reservoir. Previously the salinity control was presented first and was connected to the engineering fundamental concept of conservation of mass. The temperature control was presented in the second half of the course and was connected to the concept of conservation of energy. With the new structure of the course these sections were reversed. Thus, the course now starts with temperature control and conservation of energy then leads to sanity control and conservation of mass. The decision to make this change was based on many factors, but mostly driven by the ability to incorporate more programming scaffolding in terms of the temperature control process. Temperature control is less complex than salinity control; and therefore, more focus can be placed on building better programming competencies as the students progress towards the salinity control.

Another major change that the ENGR curriculum underwent was incorporating more programming challenges that emphasized individual accountability. The first seven classes in the curriculum require all students to build circuitry and program various tasks as individuals as opposed to before when they did it in teams. The challenges are usually started in class and finished for homework. Each student has to bring the working program to the next class to be checked by the professor. The goal of this inclusion is to increase programming competency and confidence in every student. Table 3 summarizes key changes for ENGR 121.

Table 3. Summary of key changes for ENGR 121

New Programming and Circuit Building Challenges	
Challenge	***Description***
Working with Data	Read in analog temperature values and program the sketch to find min, max, average, and average minus the min and max was incorporated to help better understand how to program the Arduino to collect and analyzing data
Simulating the Heater	Simulate the heater on and off function using an LED

Programming LEDs to indicate status	Make a red LED blink when the temperature read by the thermistor is below a certain value, and a green LED blink when the temperature read by the thermistor is above a certain value
Implementing Piezospeakers	Implement a piezospeaker and control the frequency using a series of on and off commands
Piezospeakers as Alarms	Provide an audible indicator associated with the analog reading of the thermistor
Cascading Switches and Heater Simulation	Build a cascading switch circuit (like the one they will use with their fishtank heaters) along with the thermistor circuit and simulate the heater on and off function
New Presentations	
Presentation Title	***Purpose***
Data Types	More emphasis was placed on different data types and discussion of when and why you use each type.
Conservation of Energy problems	More problems were incorporated in the classes so students will gain experience working various types of conservation of energy problems.
Conservation of Mass problems	More problems were incorporated in the classes so students will gain experience working various types of conservation of mass problems.
Flowcharts	A discussion on flowcharts was added to the content to help students think through and plan their programs.
Programming Fundamentals	A review of programming fundamentals discussed in the class was compiled into a presentation for the students to reference. Some key concepts discussed are: troubleshoot, printing to the serial monitor, main function versus user defined functions, for loops, measure analog data, if statements, millis() command, and data types.
Simple Control of Salinity	Students control the salinity by using set times to open and close the solenoid valves connected to the different water reservoirs.
Intelligent Control of Salinity	Students control the salinity by opening and closing the solenoid valves based on gain and also setting a deadtime compensation.
Practice Problems	Created practice problem bank to provide multiple problems that will help students prepare for midterm and final exams.

The ENGR 122 curriculum is centered around an open-ended smart product design. Students in the class are self-selected into teams of two to four where they design, build, and showcase a working prototype that solves a problem of their choosing. They must incorporate the Arduino microcontroller and sensors in their design. The ENGR 122 curriculum is currently being redesigned. Some of the main changes that are being done include:

- Giving students more sensors and requiring them to be implemented in class
- Homework challenges that require individuals to implement and program sensors
- Discussions on team dynamics and qualities of innovative teams
- Opportunity for students to present ideas to their peers
- Opportunity to give and receive constructive feedback from peers
- Discussions on structuring project presentations
- Better description of the university resources that can help them with their projects (maker spaces, prototyping lab, machine shop, printer services, etc.)

- More in class examples of statics problems
- More in class examples of engineering economics

It is also important to note that in each course (ENGR 120, 121, and 122) significant edits have been made to the homework. New homework problems were created for each class which was designed to increase in intensity and rigor. The intent of the new homework is to help the students understand the material better and to better prepare them for the problems they will see on the midterm and final exams.

Initial analysis of Redesign

Because the redesign for the LWTL curriculum is still in its first year, data is limited. However, we can look at initial data to get an idea of how the changes have impacted student performance. Since this is a work in progress, the researchers will look only and the overall averages of the midterm and final exam grades for corresponding classes as the preliminary analysis of the redesigned curriculum.

The initial cohorts who experienced the redesign in Spring 2017 for ENGR 120 can be compared to the cohorts in the sections that were not taking the redesign version. We can also compare these students with previous quarter offerings of the ENGR 120 curriculum. Also, since the redesigned ENGR 120 was fully implemented in fall school year of 2017-2018, we can compare their performance data to previous quarters.

A similar analysis can be conducted with the ENGR 121 students with the pilot group and the group who experienced the full implementation. However, since the full implementation is currently happening in the present quarter, complete data is not available for this cohort of students. Only the midterm data is available.

The ENGR 122 has less available data since it is currently being redesigned. Only the midterm has been given and there is no section cohort taking the class right now that is doing the old curriculum. However, we can look at the 122 performance scores from previous quarters and compare them with the current quarter's midterm data.

Before presenting the data, it should be noted that issues may occur when comparing students in each course from quarter to quarter (e.g.; ENGR 120 students in fall, winter, and spring). Students who take ENGR 120 in the fall, ENGR 121 in winter, and ENGR 122 in the spring are considered "on track." If a student takes ENGR 120 in the winter, ENGR 121 in the spring, and/or ENGR 122 in the fall, they are considered to be a "single lag" group. These students are behind typically because of math deficiencies and have to take college algebra or trigonometry before enrolling the engineering curriculum. Students who take ENGR 120 in the spring, ENGR 121 in the fall, and/or ENGR 122 in the winter are considered "double lag" and are behind for a variety of reasons including math deficiencies, failing math a previous quarter, failing engineering a previous quarter, or transferring to the university from a semester school and not being able to start in the curriculum until spring quarter.

Historically, on track student perform better than single lag students, and single lag students typically perform better than double lag students. The initial redesigns of each course occurred with double lag students. It is difficult to truly compare the double lag scores with students who are single lag or on track, but for the preliminary analysis, this will provide some idea of the impact of the redesigned curriculum.

Furthermore, the on track student data contains results from honors students. These students are only found in on track quarters and therefore typically skew the averages higher. For the analysis, the average scores on the midterm and final will be shown only with honors, without honors, and combined non-honors and honors students to provide a more points of comparison.

Table 4, Table 5, and Table 6 exhibit the data for the exam scores on both midterm and final in the ENGR 120, 121, and 122 courses, respectively. Data for the final in ENGR 122 was not included in the table since the final has not been given to the students in the revised curriculum currently being piloted. Rows that are highlighted blue indicate the initial pilot of the revised curriculum. Rows that are colored green indicate full implementations of the curriculum. Additionally, the exam scores associated with the revised curriculum are colored red for easier analysis. In each of the tables, a column was included to note if the course was conducted with on track (OT), single lag (SL), or double lag (DL) students. The column entitled "Honors" indicates whether the data includes honors and non-honors (H&N) data, only honors student data (H), and only non-honors student data (N). The school year column indicates the quarter and school year that the course was offered, where the first two number indicate the ending year of that school calendar. The third number in the school year code indicates the quarter, where 1 is fall quarter, 2 is winter quarter, and 3 is spring quarter. For example, 172 indicates the winter quarter of the 2016-2017 the school year.

Table 4. Average Midterm and Final Scores for ENGR 120

Student Type	School Year	Honors	Midterm	# Taking Midterm	Final	# Taking Final
DL	173*	N	**71.04**	26	**73.65**	20
DL	173*	N	65.05	58	61.46	45
SL	172	N	68.16	115	59.28	103
SL	162	N	66.09	136	57.85	98
SL	182	N	60.01	95	N/A	N/A
OT	181	H&N	**69.75**	440	**77.44**	361
OT	181	H	**83.96**	109	**86.13**	101
OT	181	N	**64.86**	331	**73.54**	260
OT	171	H&N	76.75	531	66.47	459
OT	171	H	89.3	183	77.25	166
OT	171	N	70.16	348	59.89	293
OT	161	H&N	75.72	576	70.66	513
OT	161	H	88.46	198	84.01	194
OT	161	N	69.13	378	63.32	319

*The first row of 173 data is for Section 001, and the second row of data was for section 002 and 003.

Table 5. Average Midterm and Final Scores for ENGR 121

ENGR 121						
Student Type	School Year	Honors	Midterm	# Taking Midterm	Final	# Taking Final
DL	181*	N	**75**	21	**79.15**	20
DL	181*	N	75.1	21	81.56	18
OT	182	H&N	**84.53**	252	N/A	N/A
OT	182	H	**89.96**	98	N/A	N/A
OT	182	N	**81.12**	154	N/A	N/A
OT	172	H&N	73.9	298	75.03	272
OT	172	H	84.21	121	82.57	121
OT	172	N	66.14	177	67.93	151
OT	162	H&N	80.57	361	69.24	347
OT	162	H	87.93	162	79.55	161
OT	162	N	74.57	199	60.32	186
OT	152	H&N	74.19	301	83.32	284
OT	152	H	82.2	141	88.38	132
OT	152	N	67.38	166	78.68	152

*The first row of 181 data is for Section 001, and the second row of data was for section 002.

Table 6. Average Midterm Scores for ENGR 122

ENGR 122				
Student Type	School Year	Honors	Midterm	# Taking Midterm
DL	182	N	**76.92**	50
DL	172	N	56.39	38
SL	181	N	58.54	87
OT	173	H&N	67.82	226
OT	173	H	75.03	115
OT	173	N	61.07	111
OT	163	H&N	69.04	283
OT	163	H	76.28	138
OT	163	N	62.15	145
OT	153	H&N	78.65	234
OT	153	H	81.89	113
OT	153	N	75.63	121

Figure 4 and Figure 5 represents the midterm and final average scores for the ENGR 120. Figure 5 and Figure 6 represents the midterm and final average scores for the ENGR 121. Figure 7 represents the midterm average scores for the ENGR 122. Data for the final in ENGR 122 was not included in a plot since the final has not been given to the students in the revised curriculum currently being piloted. The x-axis of the plots represents the quarter the course was offered using the same school year code mentioned above. The plots use blue circles to represent the average scores for students who are non-honors, green squares for the students who are in honors, and orange triangles for the combination of honors and non-honors students. Individual data points that signify an implementation of a revised version of the curriculum are colored red and are filled with a dotted texture.

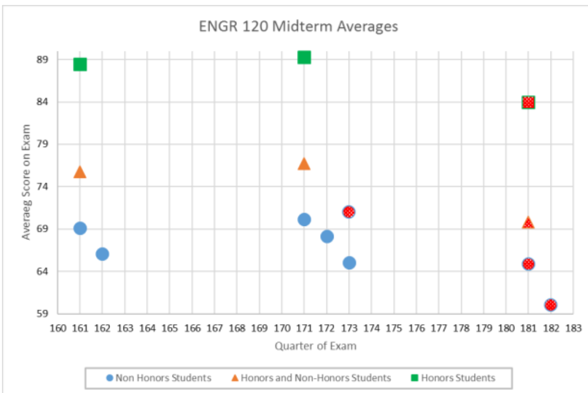

Figure 4. ENGR 120 Midterm Data

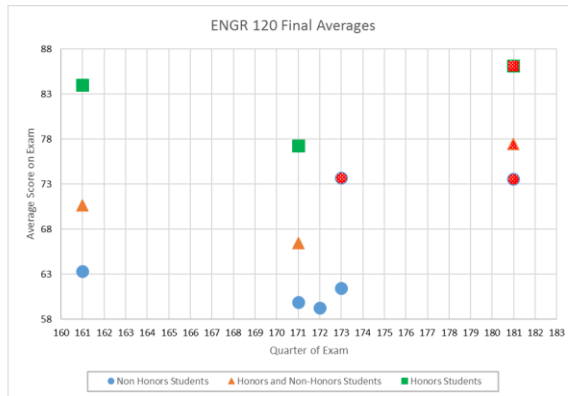

Figure 5. ENGR 120 Final Data

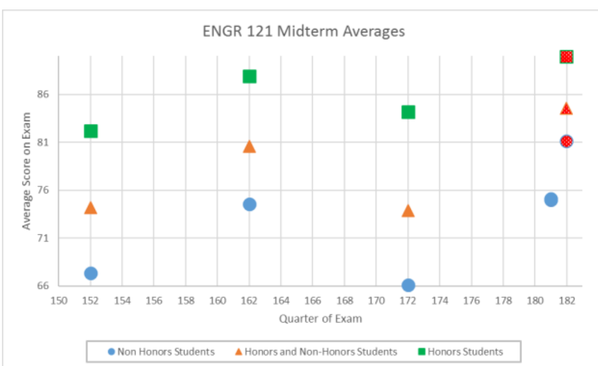

Figure 6. ENGR 121 Midterm Data

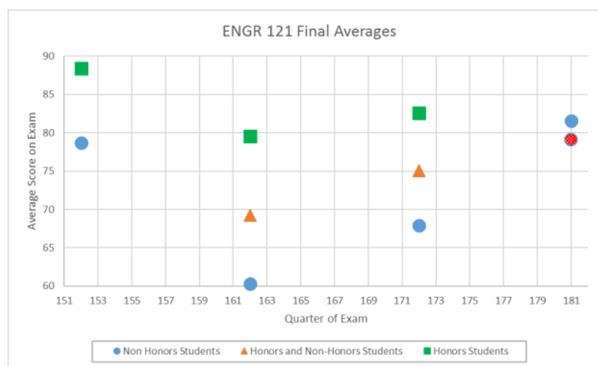

Figure 7. ENGR 121 Final Data

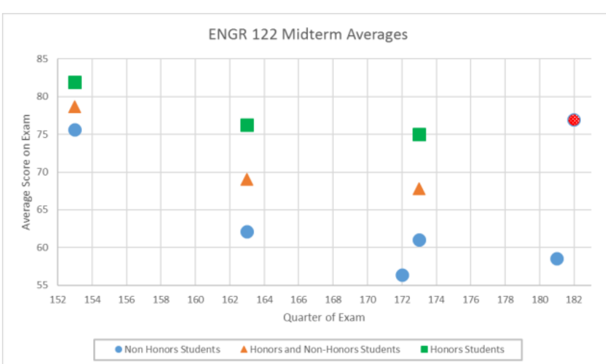

Figure 8. ENGR 122 Midterm Data

Discussion of Results

When looking at the data for the ENGR 120 midterm (173), the scores for the initial pilot group appear very promising. The average for this group was a 71.04 which is higher than any other non-honors scores. Additionally, this pilot group experienced the class at the same time two other sections were completing the course using the old curriculum. The pilot group out performed their cohort by nearly 6 points. However, when looking at the performance of the students in Fall of the 2017-2018 school year (181), the group underperformed in nearly every category (honors, non-honors, both). A few factors could have possibly influenced this downward turn of performance. This was the first full implementation of the revised content. Only one professor taught the new content for the pilot group in the previous spring quarter (173). Therefore, there were nine professors over sixteen sections that had not presented the content in the new format until this quarter. Another factor could be student quality. When discussing the performance of the engineering students with the mathematics professors, they mentioned overall poor results on the first mathematics exam taken by the same students. The same student's scores were also significantly lower on the mathematics exam than in previous years.

When looking at the scores on the final exam in 120, the pilot group again out performed all other non-honors sections as well as significantly outscoring the cohort taking the unrevised course at the same time. This group also earned a higher average score on the final than some of the course offerings when the honors and non-honors scores were combined. This achievement is noteworthy because according to the data, a non-honors group or even a DL group had not done that prior to the redesigned content. In the fall 2017-2018 school year (181) when the revised version of the course was fully implemented, the students performed better than all sections of the course when looking at their corresponding student groups (honors, non-honors, both). This is encouraging considering the students did not perform as well on the midterm.

Moving to the data for the ENGR 121 midterm, the scores for the initial pilot group also appear very promising. The average for this group was a 75 which only 0.1 lower than the cohort taking the class at the same time with the unrevised content. Aside from that section, the pilot group's score was higher than any other non-honors average score who had the unrevised version of the course. The only non-honors group to score higher was in the winter quarter of this year when the revised curriculum was offered to all students. Moreover, this full implementation of the curriculum in the winter 2017-2018 school year (182) showed significantly high averages on the midterm. All of the averages were higher compared to their comparable sections (honors, non-honors, both).

The current section of the ENGR 121 course (182, full implementation) being offered has not taken the final as of yet, but looking at the performance of the pilot groups final average compared to historical data, the revised content appears to be having a positive impact. The average score on the final with the pilot group was a 79.15. The cohort who took the unrevised version of the course along with the pilot group is the only non-honors section to score higher, but only by 2.4 points. The pilot group also performed above or very close to the ENGR 121 section scores that were a combination of honors and non-honors sections.

Finally, the ENGR 122 course is currently being piloted with a group of 52 students (182). Since only the midterm has been given to these students. Overall, the scores on the midterm for the pilot group is very encouraging. They scored an average of 76.92 which is higher than all other offerings of the ENGR 122 course for the given data aside from honors and honors/non-honors combination groups from the spring 2014-2015 (153) school year. This is interesting considering many of the questions were very similar to the ones offered in the 181 and 173 exam.

Conclusions

All together the scores for the midterms and finals in the LWTL curriculum for the revised content indicate a positive impact. The exception being the first exam of the ENGR 120 course with the full implementation group. Given that they were a lower performing group and it was the first time many of the faculty taught the course with the new structure, this low performance is noted, but not cause for much concern yet. When the course is implemented next fall (191), it will be important for the researchers to note a positive or negative trend and make adjustments accordingly. Aside from the midterm in 120 during the 181 offering, all of other pilot and full implementations have performed above or very near to the other sections.

Future Work

The averages on the midterm and final only provide a narrow view of the impact of the revised content. This analysis provides a good foundation for knowing if the revisions are moving the right or wrong direction. However, more a detailed investigation into specific questions asked on the exams could yield more conclusive results concerning changes that were made to the courses. The researchers intend to assess specific exam questions looking at whether the questions were the same and/or if the exams tested the same topic with the same level of rigor. This assessment will be used to make correlations between student comprehension on each topic of the course in the pre and post curriculum redesign.

Qualitative feedback could also yield valuable information on the impact of the course. Generally getting the views of students who have taken the revised version versus the unrevised version could provide meaningful data points. Additionally, there is a subset of students who may have taken the same class in its unrevised form as well as the revised form. Feedback from these students could prove to be very beneficial.

In addition to looking at the performance data, retention data can also provide insight on the impact of the curriculum redesign. The researchers also plan to look at the impact the new curriculum has made on retention of students to gauge the value of the revised content.

The researchers feel there are many more areas to analyze to truly understand the impact of the curricula redesign which will result in multiple studies and subsequent papers.

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