Biomedical Engineering Education Study: Developing Computer Science Acceptance in the Student Population

An Intensive Qualifying Project
Submitted to the Faculty of
Worcester Polytechnic Institute
in partial fulfillment of the requirements for the
Degree in Bachelor of Science
in
Biomedical Engineering

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Abstract

This Interactive Qualifying Project was undertaken in order to improve the Biomedical

Engineering undergraduate computer science experience while also gaining an understanding of student

sentiment towards the subject. Determining how students felt about the current computer science

curriculum would provide key information in the development of future classes. A focus on integrating

MATLAB into future classes could allow students and teachers alike to utilize the software while granting

the students the ability to hone their skills. The results of this project provide a data set to view current

student sentiment towards the computer science curriculum as well as opportunities and examples of

areas for achievable refinement.

Acknowledgments

Introduction

The utilization of MATLAB computer software has only been increasing over the last decade in many facets of engineering. MATLAB is a numerical computing environment that combines a desktop environment tuned for iterative analysis with a programming language that directly expresses matrix and array calculations [5]. With this increase in utilization comes a need for rising engineers to adapt and develop skills within MATLAB for usage within their laboratories and future jobs. As universities viewed an ever increasing need for this knowledge they attempted to implement courses and training within computer sciences and more specifically MATLAB. But there was a push back from many Biomedical engineering students on what computer sciences should be taught as well as what level of difficulty these classes should reach. With this disagreement came obstacles for student learning both in initial learning and moving deeper into computer science. Specifically in biomedical engineers at WPI students are currently required to complete one computer science "pre-requisite" during their time studying. This course was previously only offered in the Computer Science department specifically and, for most students, offered only in Python or Racket programming languages. The Biomedical Engineering department has since added a new "pre-requisite" course in MATLAB taught by the BME department. Many students sentiment towards these languages is relatively negative, viewing these choices as a "waste" of time when in the end they will be learning in mainly MATLAB. This sentiment continues for many students as they begin taking classes heavy with MATLAB and see the classes as being too "hard" for effectively learning concepts with in the language itself. With many students feeling that these classes were not being gauged towards their learning style, there seemed to be a pulling back on the energy investment by many students into these courses and therefore a decrease in the overall learning being viewed. These sentiments need to be looked into in order to determine what factors are truly causing students' trouble and how courses could possibly be gauged differently in order to

encompass more of the students attending them. Further literature analysis was looked into in order to determine optimal methods in which to increase student interaction with current material. A portion of the discussion will be dedicated to the review of literature. It is hypothesized that students with higher GPAs will be more comfortable with MATLAB, not want a constant computer science language, have more prior experience, want a hard computer science class, and view MATLAB to be more important to their future job and current major. The creation of this hypothesis is due to the fact that students with higher GPAs tend to get these better grades because they have, and continue to, challenge themselves in an academic setting. This hypothesis should be revisited during the results and discussion section in order to determine if it holds true for the questions asked within this report.

Methods

In this report Biomedical Engineers were the focus. Sentiments between the three tracks: Biomaterials, Biomechanics, and Bioinstrumentation, were determined. Relationships between low and high GPA, student selection on class difficulty, and sentiment on coding language continuity were computed.

Three surveys were conducted in total, but data from the final anonymous survey will discussed in this report. The first survey was an anonymous survey conducted in 2017 to determine learning preferences, current MATLAB skill, as well as sentiment on the prerequisite courses that were taken. An initial non-anonymous survey was conducted in 2018, however the response was too small for statistical significance with an N=3 as the largest number of responses for a focus. A second anonymous survey was conducted, encompassing those contacted in the non-anonymous survey as well as two full classes of students who represented an effective cross section of all biomedical engineering tracks.

The final anonymous survey conducted aim to determine students' feelings towards how important MATLAB was in their eyes as well as how skillful they believed themselves to be when using MATLAB. The survey contained 17 questions. The questions appeared as in the table below.

Final Anonymous Survey Questions	
1.	What is your focus in Biomedical Engineering?
2.	What is your college year?
3.	What is your GPA?
4.	Do you have a Minor?
5.	If yes, what is your Minor?
6.	What is your experience with MATLAB?
7.	If you have experience with MATLAB when was your first exposure to it?
8.	If you have experience with MATLAB how comfortable do you feel using it (ranked on a scale 0-5, 0 being not at all, 5 being very comfortable
9.	How important do you view MATLAB to your major? (ranked 0-5, 0 being not important, 5 being very important.)
10.	How important do you view MATLAB to future employment opportunities? (ranked on a scale 0-5, 0 being not important, 5 being very important.)
11.	Have you taken the BME computer science prerequisite?
12.	If you have taken the prerequisite, which class was it?
13.	How useful did you find the material in the prerequisite? (ranked on a scale from 0-5, 0 being not at all, 5 being very useful.)
14.	If your prerequisite was taught in a language different than MATLAB, would you have liked on consistent language throughout your computer science learning?
15.	If you are taking a computer science class do you believe it should be easy or hard?
16.	Explain your choice to the previous question.
17.	If a computer science class is hard, what would you do?

Table 1: Survey Questions

The data was collected anonymously using Google forms to accelerate the response time and data collection process. The individual responses were then tabulated in Excel and relationships between questions and Biomedical Engineering tracks were graphed. Standard deviation was included and Wilcox rank sum tests were run comparing every questions data from each of the three tracks to determine the p-values and difference between data sets.

The data was tabulated and analyzed utilizing Microsoft Excel in order to generate graphs of each of the data sets.

It was also important to determine if current sentiments and trends viewed within WPI were descriptive of all BME students around the country, or if this was a specifically WPI problem. Professors and students from other universities were contacted and asked about how students at their respective universities felt and viewed computer science and MATLAB more specifically. Their responses were collected and were analyzed generally to determine if their experiences were similar to those seen at WPI.

Results

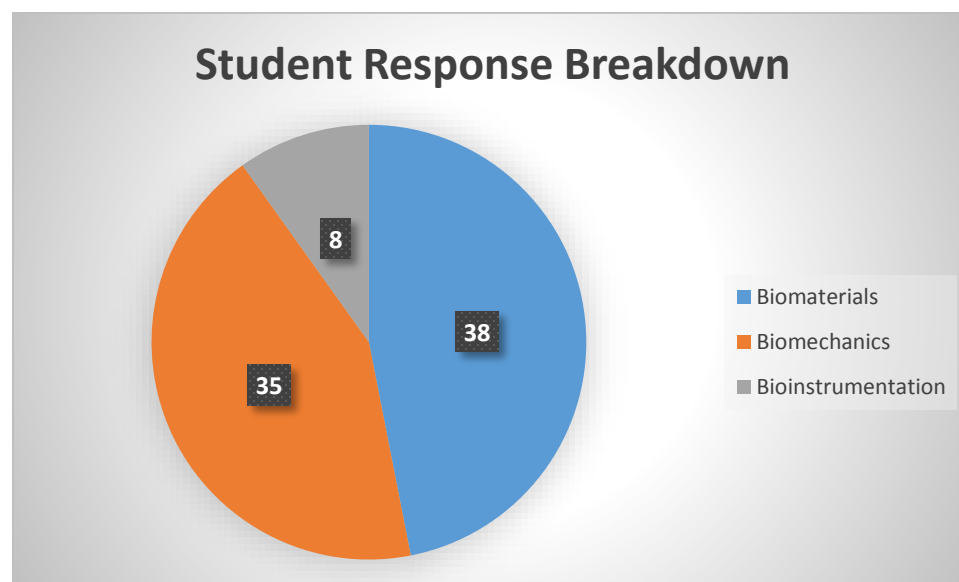## Student Response Breakdown

Figure 1: Student response breakdown by Biomedical Engineering focus: 47% Biomaterials, 43% Biomechanics, 10% Bioinstrumentation

By track of the student response gave a good representation of all tracks within biomedical engineering. Bioinstrumentation seems underrepresented because it is a less often selected track within biomedical engineering historically.

Student Response Breakdown
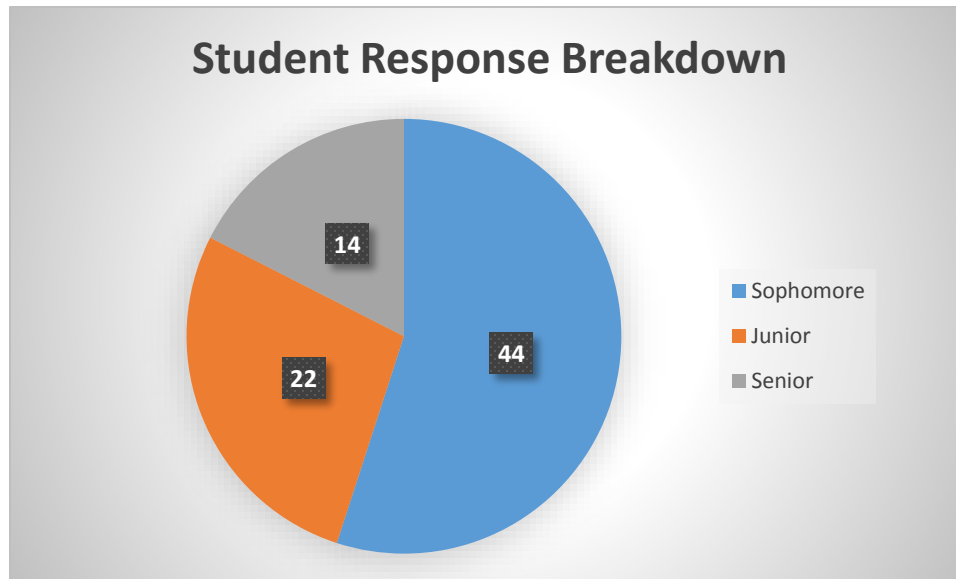
Figure 2: Student response breakdown by college year: 55% Sophomore, 27.5% Junior, 17.5% Senior

By major the student response gave a good representation of all college years within biomedical engineering. Freshman year is unrepresented in this selection for two reasons: one, freshman are much more fluid in what major they are picking and/or are still undecided into what are they are focusing in and are taking only general requirements, and 2, freshman specific classes in biomedical engineering were not offered in C or D term of the 2018 academic year and freshman specific classes for biomedical engineering are very unrepresented at WPI allowing freshman to take their general requirements their freshmen year.
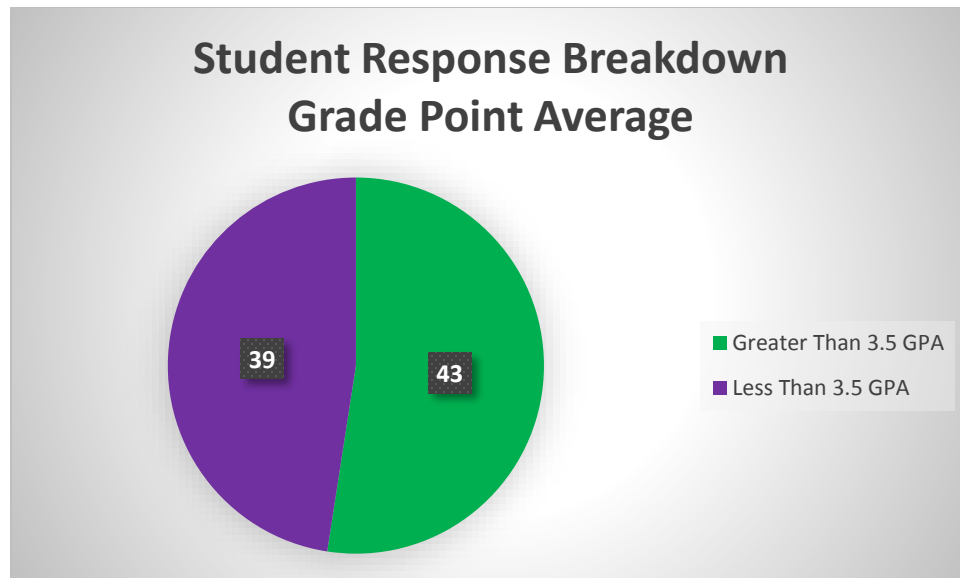
Figure 3: Student response breakdown by grade point average: 48% Low GPA, 52% High GPA

Splitting the data into two groups based upon a 3.5 grade point average or above cutoff created almost two equally sized groups to determine qualities based upon student's "success" in terms of their self-reported grades within their entire education at WPI. Any GPA cutoff could have been selected but 3.5 was chosen as a break point to attempt and separate students who are very successful and students who are not as successful.

Average Grade Point Average

Figure 4: Average GPA per group based on BME track groups

*Error Bars are standard deviation of each data set

The average GPA of the three biomedical engineering tracks as self-reported by students. P-values for comparison between tracks were Biomaterials – Biomechanics 0.7309, 0.9526 for Biomaterials – Bioinstrumentation, and 0.6733 for Biomechanics – Bioinstrumentation. Any P-value ≥ 0.05 shows rejection of the null hypothesis two data sets being compared are from continuous distributions with equal medians. This shows that on average, each track receives similar grades within their courses as shown by the large P-values. The lack of variation is important in order to show in subsequent data sets, while the tracks may have similar academic success, they may not have similar feelings or success with computer science and MATLAB.
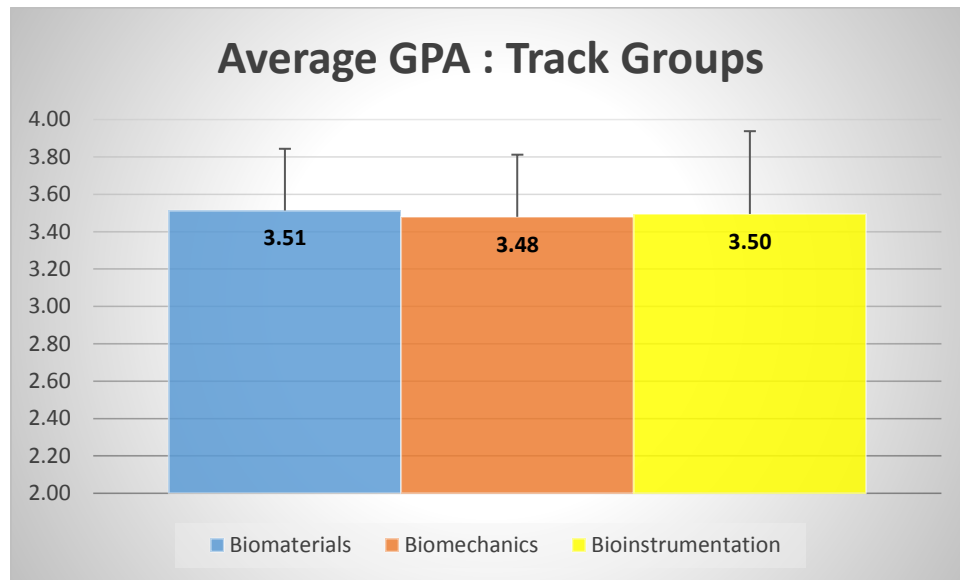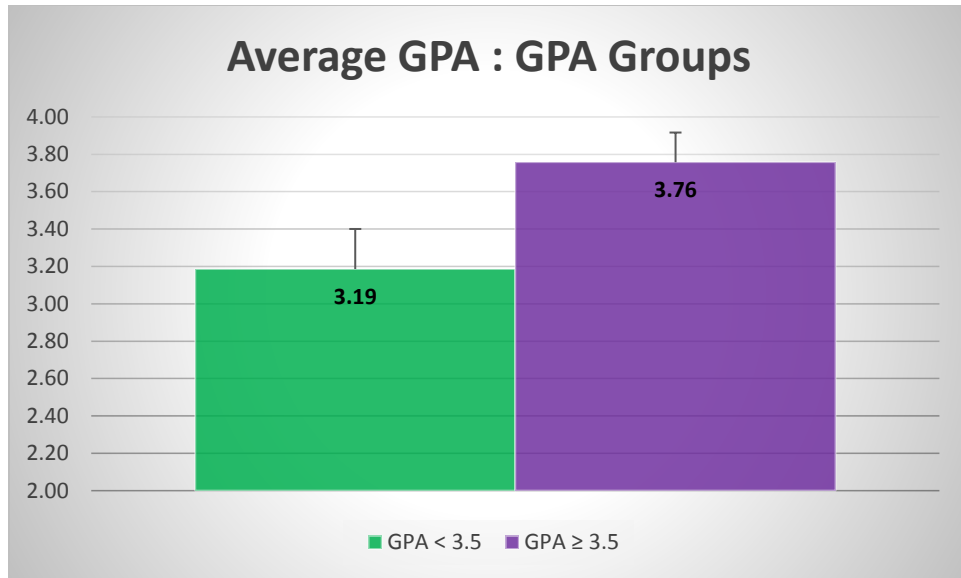
Figure 5: Average GPA per group based on GPA cutoff

*Error Bars are standard deviation of each data set

The average GPA of the less than 3.5 GPA and greater than or equal to 3.5 GPA groups. The P-value associated with comparing the two groups is 6.8371e-15. Any P-value $\geq$ 0.05 shows rejection of the null hypothesis two data sets being compared are from continuous distributions with equal means. This shows that the high and low GPA sections have an average GPA that differs by approximately .6 grade points and will allow for distinctions to be made based off of trends within high or low GPA groups.

Figure 6: Importance of MATLAB to both future job opportunities and current major based on track

*Error bars are standard deviation of each data set

**Between tracks, all data sets in this figure are statistically significant.

The importance to job scoring was based on a score 0-5 on how important the student viewed MATLAB to be for their future employment opportunities. P-values for comparison between tracks were 0.4107 fo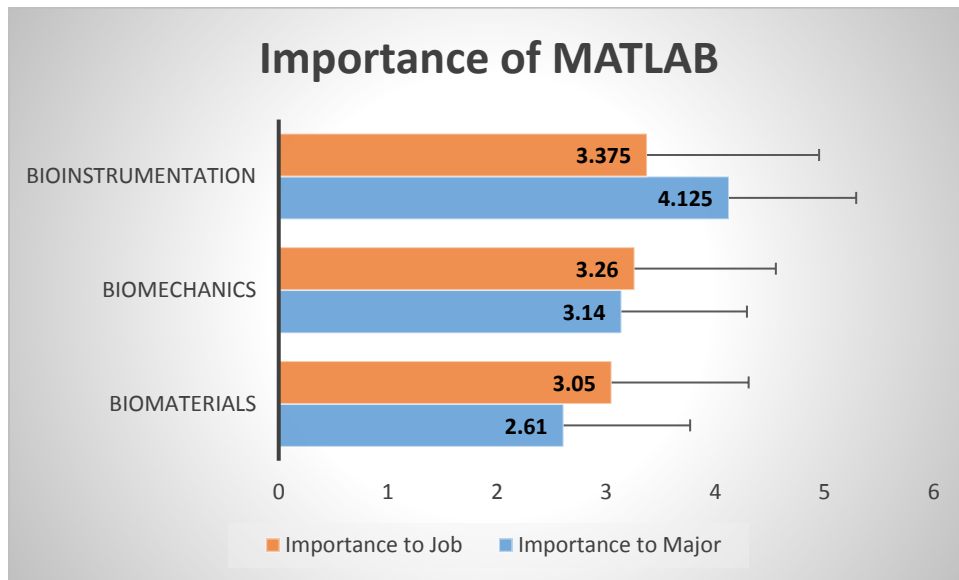r Biomaterials – Biomechanics, 0.3721 for Biomaterials – Bioinstrumentation, and 0.6414 for Biomechanics – Bioinstrumentation. The importance to major scoring was also based on a score 0-5 on how important the student viewed MATLAB to be for their major. P-values for comparison between tracks was 0.0870 for Biomaterials – Biomechanics, 0.0062 Biomaterials – Bioinstrumentation, and .0466 Biomechanics – Bioinstrumentation. Any P-value ≥ 0.05 shows rejection of the null hypothesis two data sets being compared are from continuous distributions with equal means. For importance to job, regardless of track, students felt MATLAB to be similarly important to their future job opportunities, showing that students generally believe MATLAB to be important in that regard. For importance to major, there is a relatively strong trend of increasing importance from biomaterials, to biomechanics, to

bioinstrumentation. This follows the expected trend that biomaterials utilizes the least MATLAB and

therefore should view it less important the other tracks, biomechanics was then to be second as

MATLAB is utilized more often, and then bioinstrumentation as computer science is a large component

of the track itself. With the P-values calculated less than or slightly larger than .05, each of the groups is

significantly different than the others. This is important to note as students who view MATLAB to be less

important in their lives, when tasked with learning and developing skills within MATLAB will tend to

invest less energy and time due to the fact that they view it as less important to their overall success.
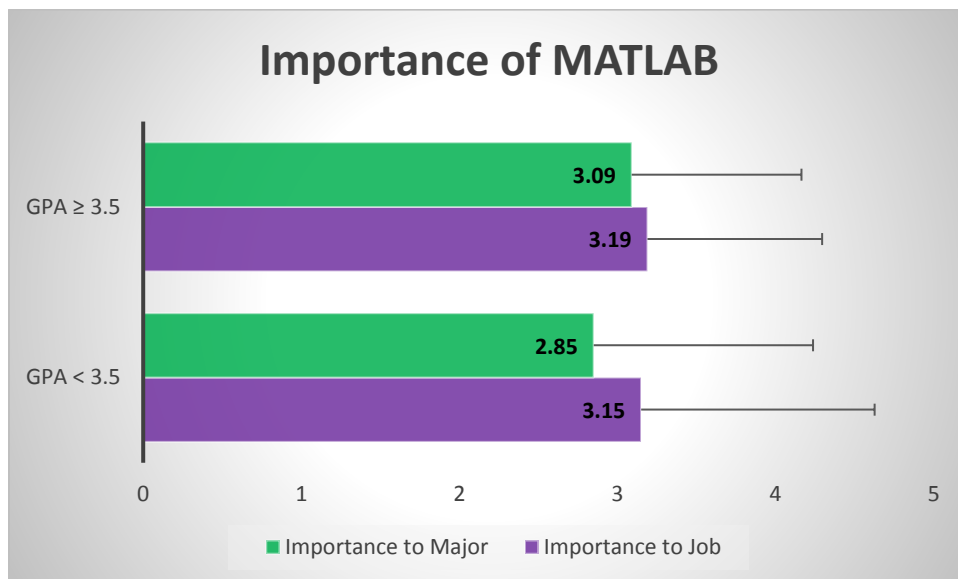
Figure 7: Importance of MATLAB to both future job opportunities and current major based on GPA

*Error bars are standard deviation of each data set

The importance to job scoring was based on a score 0-5 on how important the student viewed

MATLAB to be in their future employment opportunities. The P-value for job importance when

compared between the two GPA groups was 0.905. The importance to major scoring was based on a

score 0-5 on how important the student viewed MATLAB to be for their major. The P-value for major

importance when compared between the two GPA groups was 0.3803. Any P-value ≥ 0.05 shows

rejection of the null hypothesis two data sets being compared are from continuous distributions with

equal means. This displays that regardless of GPA, students gauge the importance of MATLAB to their future jobs and current majors similarly. This is important to show that students with greater success within school did not view MATLAB as being more important to their futures than students with less success within school.

<u>Comfortability with MATLAB</u>

Figure 8: Comfortability with MATLAB based on track

***Error bars are standard deviation of each data set**

Comfortability with MATLAB was based on a score 0-5 on how comfortable students felt using MATLAB on their own. Biomaterials had an average comfortability score of 0.82, Biomechanics an average of 1.51, and Bioinstrumentation an average of 2. P-values for comparison between tracks were 0.0297 for Biomaterials – Biomechanics, 0.0375 Biomaterials – Bioinstrumentation, and 0.4698 Biomechanics – Bioinstrumentation. P-values ≥ .05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. This data shows that comfortability with MATLAB is much less within biomaterials tracks than biomechanics or

bioinstrumentation tracks. A lack of comfortability within biomaterials tracks correlates well with the expected trend of most students attempting to avoid MATLAB heavy tracks, such as bioinstrumentation. The increased, and similar levels of, comfortability within biomechanics and bioinstrumentation show that the expected increase in utilization of MATLAB by these two tracks, correlates with higher comfortability scores. This relationship displays the issue with attempting to incorporate MATLAB into classes later in a student's career, there is a wildly varying level of skill within the student body and gauging class work and problems to this broad of a range of student skill could prove difficult without leaving one group behind or having one group think the work is too easy.
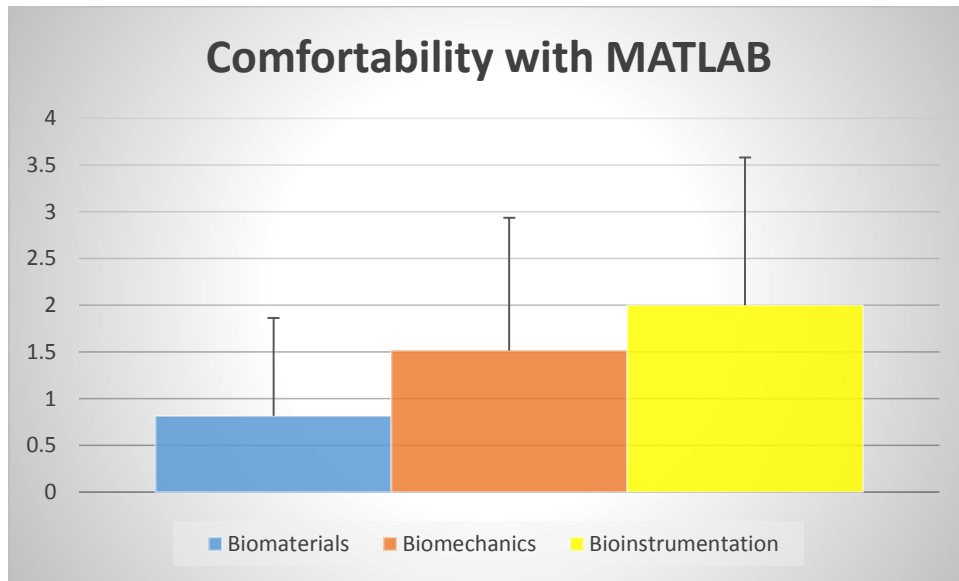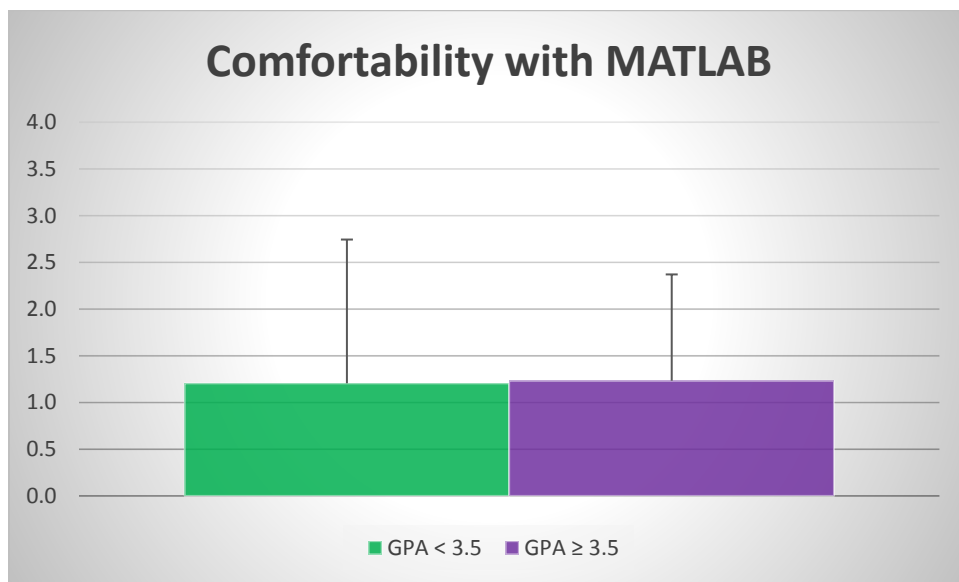

Figure 9: Comfortability with MATLAB based on GPA cutoff
*Error bars are standard deviation of each data set

Comfortability with MATLAB was based on a score 0-5 on how comfortable students felt using MATLAB on their own. The GPA < 3.5 group had an average comfortability score of 1.21 while the GPA ≥ 3.5 group had an average score of 1.23. The P-value associated with comparing the two groups was 0.4629. P-values ≥ .05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. The data displays that students are similarly

comfortable with MATLAB regardless of their GPA. This relationship is relevant to show that students

with greater academic success, and who may be thought to dedicate more hours to preparing

themselves for school, do not feel more advanced than students with less academic success, who may

be thought of dedicating less hours to preparing for academics.

Prior Experience

Figure 10: Average prior experience with MATLAB based on track

*Error bars are standard deviation of each data set

Average prior experience with MATLAB was based upon a selection of past experience with

MATLAB between 0 and >3 classes with one class and 2-3 classes being the intermediate choices. Upon

entry the selection was then changed to a numerical value pertaining the specific selection 0,1,2.5, and

3.5 were associated with 0, one class, 2-3 classes, and >3 classes respectively. The amount of each

selection was then weighted with its numerical value after being divided by the total number of

responses to achieve the averages displayed in figure 5. Biomaterials had an average prior experience of

0.89 classes, Biomechanics an average of 1.5 classes, and Bioinstrumentation an average of 1.25 classes. P-values for comparison between tracks were 0.0335 for Biomaterials – Biomechanics, 0.2516 Biomaterials – Bioinstrumentation, and 0.7445 Biomechanics – Bioinstrumentation. P-values ≥ 0.05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. Data in this section displays that tracks expected to utilize MATLAB more often, biomechanics and bioinstrumentation, have significantly higher levels of prior experience than students who utilize MATLAB less often, biomaterials. Students overall had, on average, 1.2 classes of prior experience in MATLAB. With essentially one class of introduction it is important to see that students do not have the prior exposure to the subject in order to utilize MATLAB and it tools for a class which calls for higher level functions to be developed and used for data analysis.
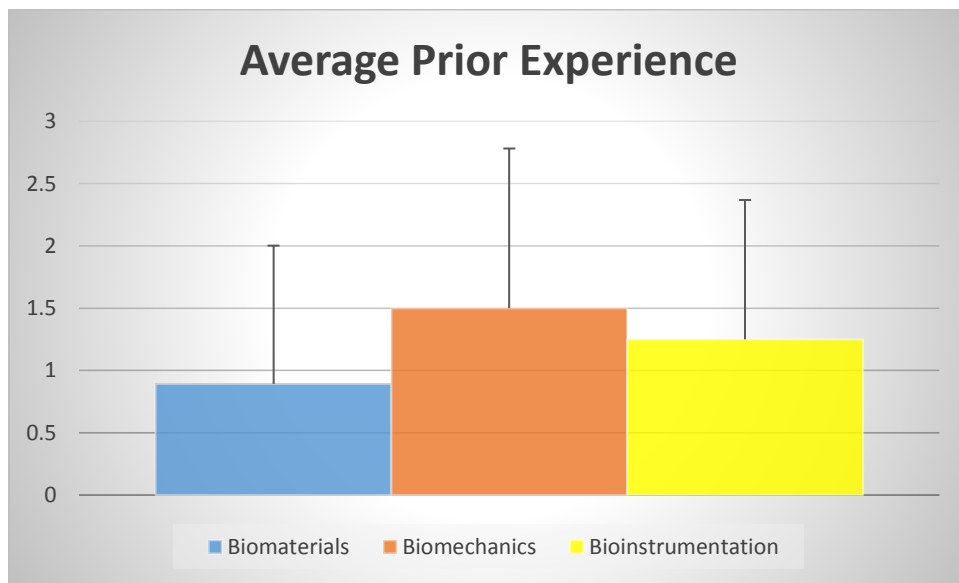

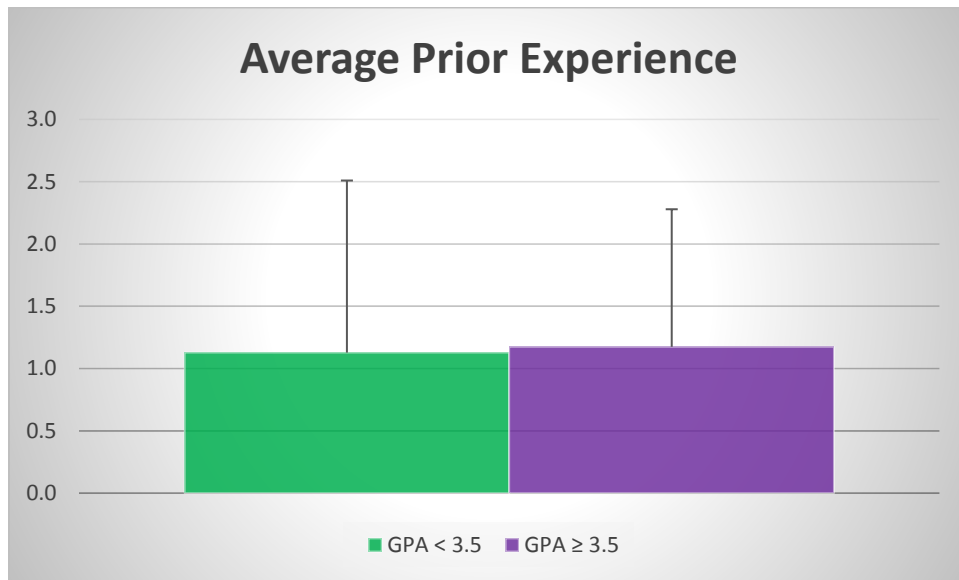**Figure 11: Average prior experience based on GPA cutoff**

*Error bars are standard deviation of each data set

Average prior experience based on GPA cutoff was determined utilizing the same methods as Figure 10. Average experience for the GPA < 3.5 group was 1.13 classes and was an average of 1.17 classes for the GPA ≥ 3.5 group. The P-value associated with comparing the two groups was 0.9529. P-

values ≥ 0.05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. This shows that students have similar prior experience with MATLAB regardless of GPA. This presents the fact that students with a higher GPA have not gone out of their way to take more classes involving MATLAB when compared to students with lower GPAs overall.

All biomedical engineering students at WPI are required to take a computer science prerequisite in order to graduate. This prerequisite is currently not taught in MATLAB but most commonly in Python or Racket. Determining student sentiment pertaining to their experience through the prerequisite class is important in developing future classes that will better assist in teaching students valuable skills and knowledge of computer science.
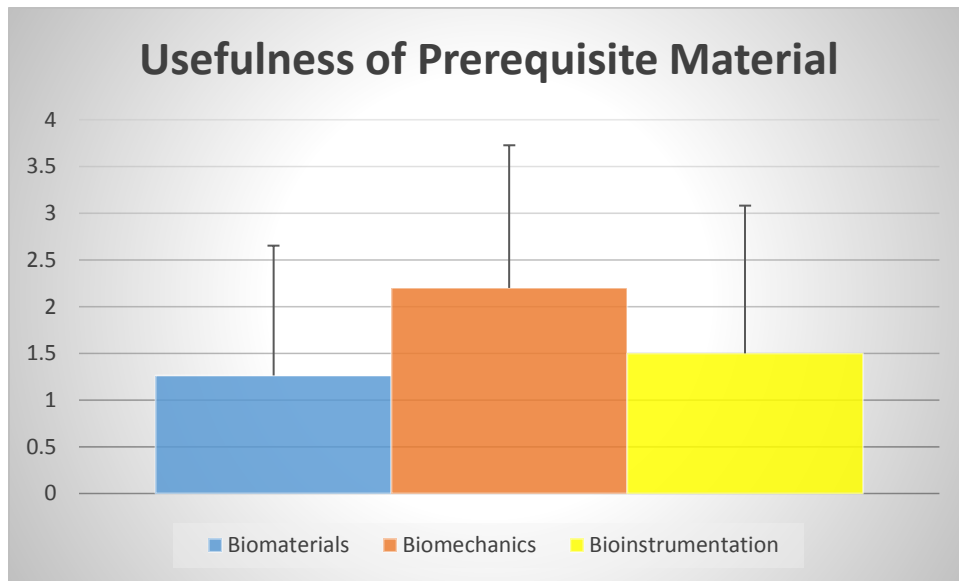
Prerequisite Material Usefulness

Figure 12: Usefulness of prerequisite material based on student sentiment
*Error bars are standard deviation of each data set

Usefulness of prerequisite material was determined based upon a score 0-5 of how useful students felt their computer science prerequisite class' material was. Biomaterials determined an

average usefulness to be 1.26, Biomechanics an average of 2.2, and Bioinstrumentation an average of 1.5. P-values used for comparison between tracks were 0.008 for Biomaterials – Biomechanics, 0.7508 Biomaterials – Bioinstrumentation, and 0.2058 Biomechanics – Bioinstrumentation. P-values ≥ 0.05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. This relationship displays that students who utilize computer science more often, biomechanics and bioinstrumentation, view their introductory computer science experience to have been more useful than students who do not, biomaterials.
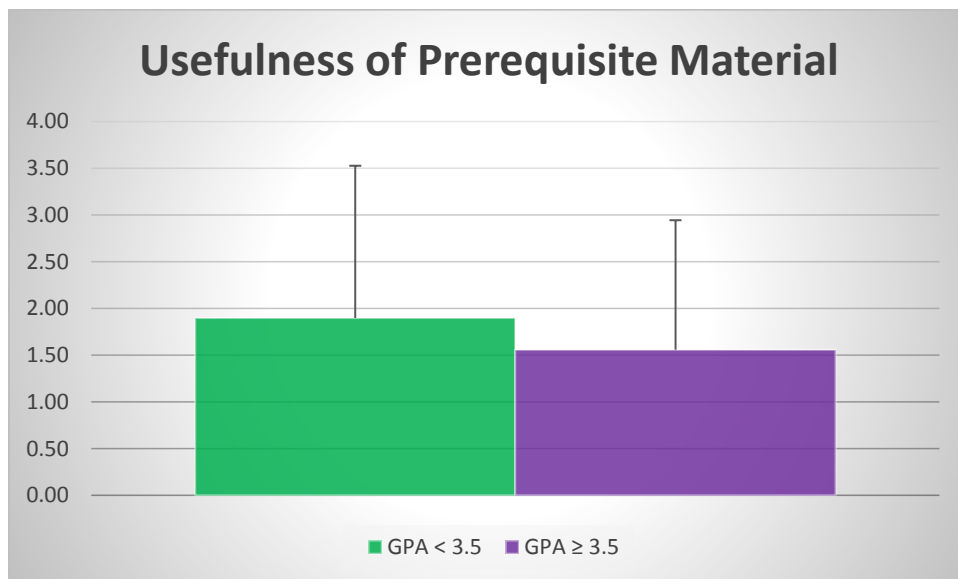
Figure 13: Usefulness of prerequisite material based on GPA cutoff

*Error bars are standard deviation of each data set

Usefulness of prerequisite material based on GPA cutoff was determined based on a score 0-5 of how useful students felt their computer science prerequisite class' material was. The average usefulness score for the GPA < 3.5 group was 1.9 and the average for the GPA ≥ 3.5 group was 1.56. The P-value used associated with comparing these two groups was 0.3973. P-values ≥ 0.05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. This data is crucial in expelling the idea that the original hypothesis was correct. Believing that students

with higher GPAs care more about school or would focus and look on the brighter side of certain classes is completely incorrect when looking at this data and all subsequent and previous information. Students with lower GPAs have very similar sentiments and choices when compared to students with higher GPAs. It is incorrect to believe that this relationship would hold up in all situations, but here it is most definitely correct.

Computer Science Difficulty Selection
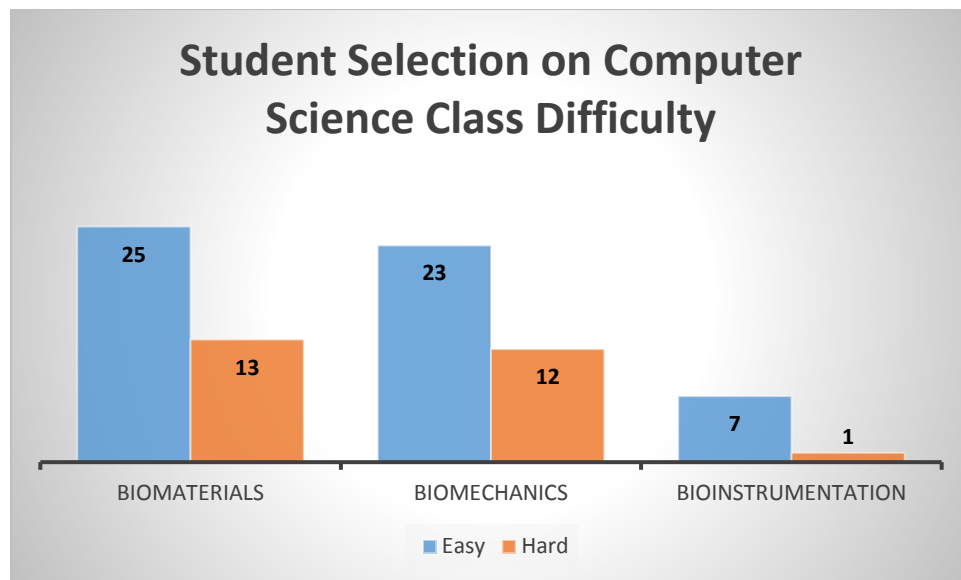
Figure 14: Student selection on computer science class difficulty

Student sentiment on computer science class difficulty was determined based on a binary question of either yes or no to whether the students believed a computer science class should be easy or hard. P-values used for comparison between tracks were 1 for Biomaterials – Biomechanics, 0.2374 for Biomaterials – Bioinstrumentation, and 0.2393 for Biomechanics – Bioinstrumentation. P-values ≥ 0.05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. The similarities found between biomechanics and biomaterials, as well

as the overwhelming 7 to 1 ratio found in bioinstrumentation, show that students would rather start of learning a computer science language on an easier, introductory level than a hard, laborious one.
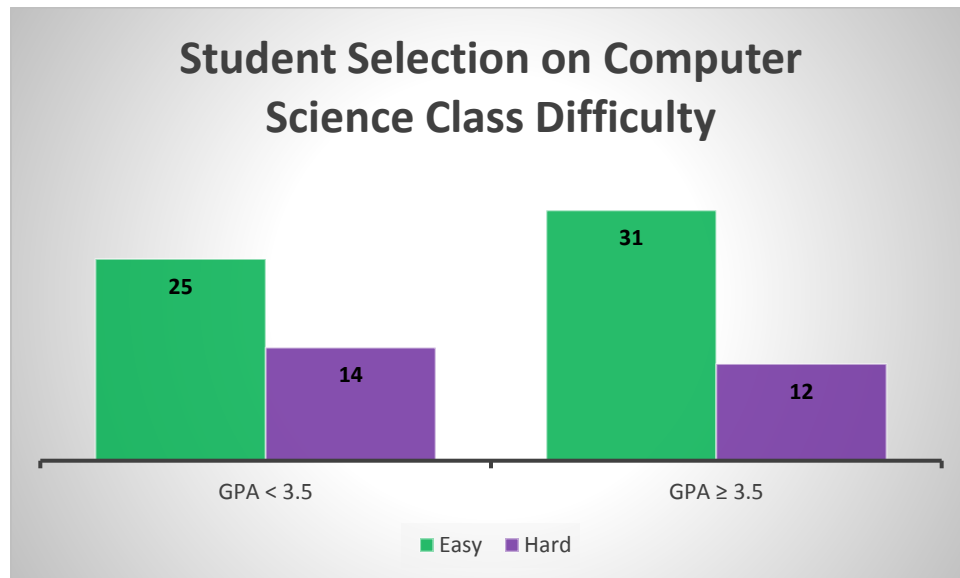
Figure 15: Student selection on computer science class difficulty based on GPA cutoff

Student sentiment on difficulty was determined in the same manner as figure 14. The P-value associated with comparing these two groups was 0.4437. P-values ≥ 0.05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. This data set also assists in dispelling the original hypothesis, high GPA students do not significantly prefer a more difficult computer sciences classes when compared to low GPA students.

Programming Language Consistency
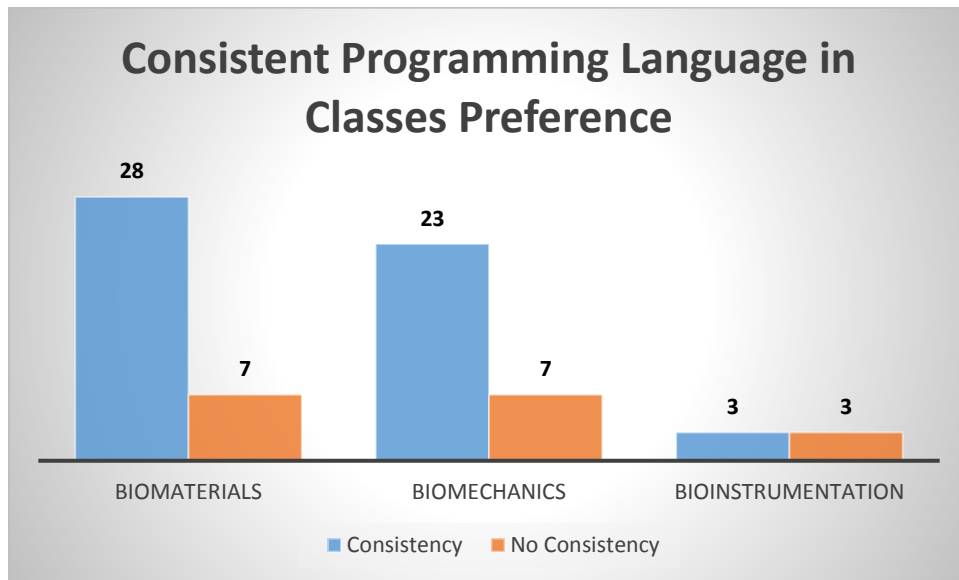
Figure 16: Consistent programming language in classes student preference

Student preference on consistent programming language was determined based upon an open

response to the question would you have liked one consistent language throughout your computer

science learning? Any answers of N/A or other indiscernible answers were not included in this data set.

P-values used for comparisons between tracks were 0.2756 for Biomaterials – Biomechanics, 0.1717 for

Biomaterials – Bioinstrumentation, and 0.5067 for Biomechanics – Bioinstrumentation. P-values ≥ 0.05

show rejection of the null hypothesis that the two data sets being compared are from continuous

distributions with equal means. With the valid responses from bioinstrumentation only giving an N=6 its

significance is very low. But the overwhelming signal from biomaterials and biomechanics is that

students much prefer a learning a single consistent computer science language than multiple semi-

disjointed ones. This is important because currently students start their introductory course in a

different language than MATLAB and then are tasked with getting up to speed very rapidly in a class that

may require it to be used exclusively.
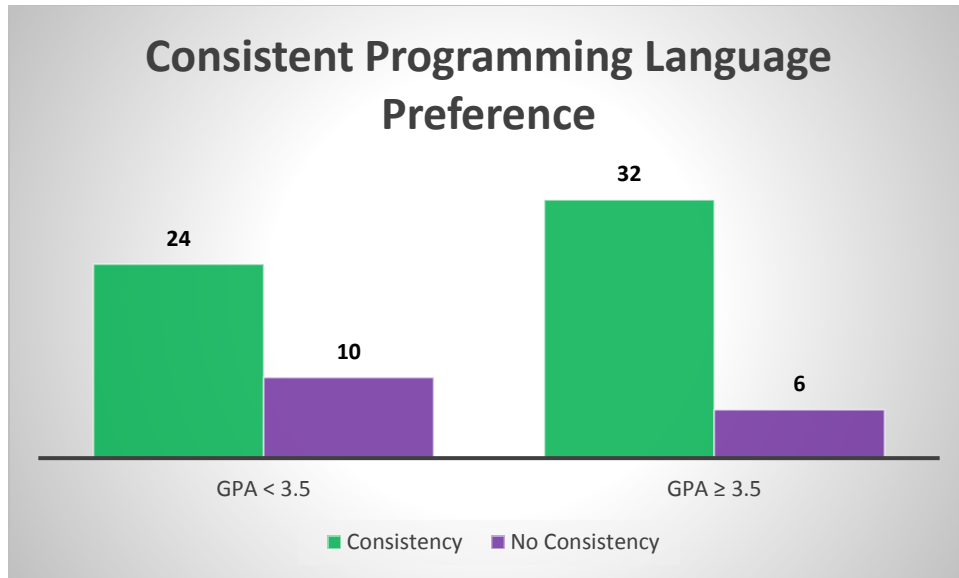
Figure 17: Consistent programming language student preference based on GPA cutoff

Student preference on programming language consistency was determined based upon an open response to the question would you have liked one consistent language throughout your computer science learning? Any answers of N/A or other indiscernible answers were excluded from this grouping. The P-value associated with comparing these two groups was 0.1185. P-values ≥ 0.05 show rejection of the null hypothesis that the two data sets being compared are from continuous distributions with equal means. While it may have been hypothesized that students with higher GPAs would see merit in multiple languages more often than students with low GPAs that has been determined to be false in this setting. Both low and high GPA students believe that they would rather undertake one language from the beginning of their education and carry that knowledge with them throughout their time at college.

Other School Trends

Several different Universities were reached out to for information on current trends within their Biomedical engineering departments and possible solutions that have been implemented. Of the Universities that responded Boston University was the only institution where students said they received introduction to MATLAB at the beginning to their engineering education and then were tasked

with utilizing it throughout their education. A Yale University professor responded acknowledging that current trends within their university were similar to that at WPI where students do not view MATLAB and computer science as a whole as being important to their futures. While they did note that students are beginning to realize that computer science skills are becoming more and more useful. Students from Yale also commented on the situation and noted that even though students are recognizing the value of MATLAB and other computer science skills, students still hold a certain disdain towards the subject. The curriculum is quite open there and allows students to choose what classes they want to take, similarly to WPI. This leads to the trend of most students focusing on the biomechanics track and avoiding a track with a heavy focus on MATLAB, such as bioimaging. It was also noted that students who aim to be doctors or go down a bioengineering path will not be enthusiastic about developing their programming skills as they will not need to utilize them.

At Boston University students responded noting that a majority of the biomedical engineering students view their freshman introductory MATLAB course as a baseline for computer programming. As students progress through their education at the university engineering professors teach with the assumption that each student has a working knowledge of MATLAB and will need to utilize that knowledge in many different classes. It is also key to note that a significant portion, mostly bio-engineers, will not associate with or focus upon MATLAB or computer science as a whole as it does not pertain to their path as much as other students.

At the University of Connecticut a professor noted that students there also felt that computer science is not very important to their future.

From the University of Vermont a professor noted that students generally want coding experience, but many students find MATLAB complex and difficult. The largest complaint that they have

heard has been that students feel they take classes related to MATLAB too early on in their education and then do not utilize those skills until much later on in their education.

Discussion

Through literature research several key aspects about learning and common misconceptions therein were collected. One important lesson to be learned is that "individuals learn best when they are in a context that provides a moderate challenge… but they know enough to get started and have additional support for reaching a new level of understanding." [1]. This explains that if a student is exposed to a task that is far above their current knowledge they will "[feel] threatened and "downshifts" in a self-protection mode." [1]. So a strong knowledge base is required for a student to feel comfortable and then sufficient support is required through the learning process in order to allow for mistakes to be made and for students to "risk a leap into the unknown." [1].

Another possible struggle that currents students may be experiencing is in the creation of their own "mental models". Mental models are described as "[the] collection of mental patterns people build to organize their experiences related to a particular topic." [2] But a through the development of these mental models, students may have collected contradictory models. With contradictory models within their mind, when tasked to complete a challenge that incorporates portions of this topic, students may run into the issue of having contradictory information to attempt and solve a problem. This would increase the time required in order to solve the problem due to an internal ideological conflict within the person who had made this mental model and a self-doubt by that same person on other information that they had remembered.

To understand the reasoning behind student decision to invest time and energy into working on a certain subject or not is extremely important in following the shifting trends of students within the classroom. One of the biggest things that must be kept in mind, is that in any classroom a certain subset of students will not feel they should invest as much time as the other students due to the fact that their future and current directions do not align with the topics being covered. This was shown to be relevant in other Universities as stated in the previous section. It has been found that students who are working in topics not aligned with their future goals will utilize different problem solving methods than if they were in a topic more connected to their future. These different problem solving techniques most commonly involve a reduction in the overall time investment into the non-connected topics [3]. Connecting this to the survey information, the lower overall scores in many categories given by the biomaterials tracks could be related to the fact that they do not feel that learning coding and MATLAB holds much merit for their future endeavors. With this in mind, it would make sense also that students in biomechanics and bioinstrumentation would have higher overall scores as both of those tracks utilize coding and MATLAB more often than biomaterials. However, MATLAB is still a useful tool to solve engineering problems and analyze data so a focus should be made on methods and ways to connect learning coding from a biomaterials stand point in order to give the topic more impact to those students. With the possibility that students entering a class come from different backgrounds and have vastly different goals it is important to continuously bring in real world context from varying locations within industry in order to attempt to connect with all students on some level. Displaying the usefulness of MATLAB and the different problem solving strategies employed in vastly differing contexts, from MRI visual analysis to deep learning neural networks to quantitative finance and risk management, can allow for students aspiring to be doctors or patent lawyers, those who could possibly see some of the least merit in MATLAB, to understand the useful implications that studying and developing skills in MATLAB can have for their futures.

Utilizing this information taken from previous studies will allow for coordination of curriculum advancements to better reach the entire biomedical engineering student body. Combining the literature review with the trends found within the data can allow for a more targeted class development in order to increase student engagement within the classroom. Through the literature, the student side of learning MATLAB can be seen more clearly and must be taken into account when determining the difficulty of assignments. Development of a steady increase in difficulty will allow for students to continuously build confidence while having enough challenge to maintain constant optimal time investment. It is also crucial that students own knowledge is checked within the course in order to assure that the students have developed correct assumptions and knowledge throughout the course and have not collected contradictory information.

The immediate trend that is visible based off the survey is the fact only 8 Bioinstrumentation majors responded when 38 and 35 Biomaterials and Biomechanics majors responded. This displays an interesting possible relationship that less students choose the bioinstrumentation track than that of either Biomaterials or Biomechanics. The classes that were surveyed were both requirements necessary of all majors in Biomedical Engineering to take in order to graduate and yet still out of approximately 150 possible students to respond only 8 were focusing in Bioinstrumentation. This coincides with responses from other universities, such as Boston University and Yale, by both students and faculty that many biomedical engineering students at these universities harbor a fear or dislike for MATLAB and will go into tracks and focuses that attempt to avoid computer science as much as possible. Even with the growing acceptance that learning MATLAB is largely positive when seeking a job, students seem to believe that they could just learn it later when it is more necessary. It would seem this trend is also occurring at WPI where students do not have an interest in learning MATLAB and will focus on Biomechanics or Biomaterials instead. As shown in the results of Figure 3 students in Biomaterials and

Biomechanics view MATLAB as being less important to their future job opportunities and current major than Bioinstrumentation students. Figure 4 and 5 also display that Bioinstrumentation students feel the most comfortable utilizing MATLAB even when they do not have the most prior experience using MATLAB when compared to Biomechanics and Biomaterials students.

Most schools seem to not focus on MATLAB or make attempts to introduce students to it early on in their engineering education. This is emphasized by accounts from students and faculty at Yale, where students are allowed to choose their own electives and trend towards avoiding any class with a focus on MATLAB. This, coupled with most student's lack of interest for computer science and MATLAB in the first place, leads to the selection of classes and majors that do not focus on it and thus reinforces a weakness in MATLAB. Several schools, such as WPI and Yale, also divert coursework, in classes not focused on programming, away from teaching students MATLAB or giving out problems that could require MATLAB as there is only so much time in a semester. Teachers also have shifted their focuses away from forcing students to do something they dislike and complain about after consistent complaints and possible underperformance from the students. With many students not having basic knowledge in the subject and the advanced level of the problem being presented to them, students are forced to teach themselves MATLAB in many cases and invest much more time than for a regular assignment. The lack of a baseline or general understanding restricts what professors can show students in relationship to real world problems that utilize MATLAB and other complex programs which require a working knowledge of computer science. Boston University aims to foster a culture of computer science understanding within their biomedical engineering department and start students off with an introductory course in MATLAB. By doing this teachers and students alike can utilize MATLAB in many facets of their teaching and learning approaches, assisting in broadening their understanding and honing their skills for future opportunities and possible future jobs. If more universities would follow these few examples and place MATLAB as a key component in the learning and teaching structure of their program

then students would most likely follow right along. The biggest issue is not fostering an environment of MATLAB utilization and putting students into classes to nurture their working knowledge of the subject which has to be a focus if changes are wanted to be made.

To go along with the previous remark the students also overwhelming want one continuous computer science language to be taught to them. Of 71 valid responses, 54 or 76% said they would rather have learned only one computer science language compared to 17 or 24% who said they would want to learn multiple languages. Rather than starting their introductory course with a language that they most likely will never see again, why not take the successful examples as mentioned before and pick one language, possibly MATLAB, and introduce the students to it early. WPI has taken steps in order to begin students' curriculum with a strong background in MATLAB with a new introductory course on the subject. Reinforcing it throughout their entire education to breakdown any barriers to learning that they could have and doing so would also change the response to how useful students view their prerequisite courses. Where the average score is 1.69 out of 5 now, students would most likely raise how useful they viewed their introductory material if it was more widely used in both their university and in the real world, much like MATLAB.

Another important distinction that must be brought out of this data is that student sentiment on computer science class difficulty, figure 7, shows students are not looking for the easy way out but are looking to gain an understanding and a working knowledge of the subject before being thrown out into more difficult exercises. This information comes from the long answer question asking students to explain their choice of wanting a difficult computer science class or an easy one. Out of 81 valid responses 55 or 68% preferred an easy computer science class compared to 26 or 32% who preferred a hard computer science class. The majority of student's seem to believe that, as many subjects do, a computer science class should start off simple and engaging and then progress into more difficult complex areas. Through an introductory course that begins a student's exposure to a programming it

should display the basics in an approachable and achievable manner. This lays the groundwork for every other class to utilize these new skills developed by the students themselves into increasingly more complex situations but the key is initial engagement, forcing students to fight to barely pass does not develop fondness for that subject, but displaying real world context while developing basic understanding can raise a student's interest and appreciation towards the subject. Then continuingly reinforcing what has been learned while extending their knowledge to new, more applicable examples will increase confidence, satisfaction, and overall happiness when asked to utilize these skills. It is important, as seen through the literature review, initial engagement can be ruined if a subject is brought on too strong. Students ""downshifts" in a self-protection mode." [1] and it is very hard to get them out of that mindset. Proper thought must be placed into developing a coordinated ascension towards more complex material while maintaining accomplishable goals and fostering a strong understanding of the baseline material.

A general takeaway that has come up several times during data collection is the fact that many students do not view MATLAB as having an application in the real world. This feeling has been seen to be mainly due to lack of relevance within actual coursework as well as feeling that current industry standards do not incorporate MATLAB and there is some way to work around not having that skill later in life. When people believe that something is not useful or something is literally not useful to them, they are going to be doctors or going into a field devoid of MATLAB, they are going to have a hard time truly investing their mental and physical energy into a course focused upon that. So it is important to know that a portion of any class will be less invested than the rest due to their goals. But, for the other students within the courses it is crucial that real world significance be brought into the class by way of examples or professionals coming in and talking to bring some real-world significance to the course. By giving students a view of how what they are doing now could be applied in the real world develops confidence that the investment students are putting now will pay off in the long run because it is an

extremely applicable skill. Bringing in exercises that incorporate real world data, in a manner that does not vault past the current difficulty standards set within the course, would allow students hands on work with a multitude of areas and opportunities to feel good about having a working knowledge in MATLAB. Bringing in current experts in their field who utilize MATLAB on an everyday basis and who could display some captivating visuals from their work could also go a long way into raising student interest. A further opportunity to collaborate with these experts by the students could be worth dividends by allowing for students to gain experience in industry and make a useful real-world connection that could assist them in their future.

Taking into account the sentiment from all of the responses based on BME tracks included in this report, computer science is hard and is not presented approachably at WPI which leads to students lacking passion for the subject and seeking different routes to circumvent utilizing computer science. This is exemplified through figure 4 with the comfortability of students with MATLAB. The smallest overall response group, Bioinstrumentation with 8 responses, has the highest average comfortability score of 2 out of 5. Biomechanics follows behind with a sample size of 35 and an average score of 1.51. Biomaterials is last with a sample size of 38 and an average score of .82. The students who are most comfortable with computer science and MATLAB have biased their trackdecision towards Bioinstrumentation while students who are much less comfortable with MATLAB have a much higher bias for Biomaterials. The fact that computer science portrays itself in a less than positive light towards new biomedical engineers can be displayed by the numbers. Figure 1 and 2 display that of the 80 valid responses to the survey; 44 or 55% are Sophomores, 22 or 27.5% are Juniors, and 14 or 17.5% are Seniors. Of every response, only 8 or 10% of students selected Bioinstrumentation as their focus. With the survey reaching 41% of the 108 Sophomore Biomedical Engineers and 35% of the 64 Junior Biomedical Engineers [4], if there was a different trend then it would have been displayed by the reach of the survey. This brings up the point that students may not be exposed enough to bioinstrumentation,

computer science, or MATLAB early on in their academic careers at WPI. By not being exposed they develop habits and interests in other areas and when exposed to those areas later on, do not see them as being useful or interesting. Requiring a MATLAB course at the initiation of a students' biomedical engineering education would allow for the students to be exposed during their formative years where decisions to focus on a certain field are made. Developing their working knowledge of MATLAB as early as possible would allow for improvement of it throughout their time at WPI. Students may also be exposed to computer science or MATLAB early on but not have the subjects reinforced through classes and therefor do not see the benefits and can only see obstacles they must overcome in order to earn a degree. If every class utilized MATLAB in some capacity, the students' working knowledge could be constantly strengthened. This would allow for a better time both professor and pupil, the professors could utilize their students' skills to further their depth of education and the students would have an ever advancing knowledge in an extremely useful form of programming that could be utilized in almost every facet of their engineering education.

Through data collection and analysis an overlying hypothesis had always prevailed, it being that students with higher GPAs would more likely be positive about the current situation with multiple computer languages being taught and students with lower GPAs would be more negative towards the current situation. In order to determine this hypothesis the data had to be broken up into two groups, one of the students with high GPAs and one with the students with low GPAs. A cutoff was set at a GPA of 3.5, so all entries greater than or equal to 3.5 were included in the higher GPA and all lower were placed into the lower GPA group. This cutoff point created two sections with almost identically sized populations and allowed for comparisons to be made similarly to how comparisons were made with the different biomedical engineering tracks. Every relationship was run a second time, but this time looking at a comparison between lower and higher GPA groupings. Other than the initial P-value comparison of if the two different GPA groupings were different, returning a P-value of 6.8371e-15 for figure 5, no

other comparison yielded a statistically significant different P-value (0.05 ≥ P) when comparing the two

GPA groupings on every crucial question asked on the survey. This displayed that the initial hypothesis

was incorrect and all students were experiencing computer science at WPI in a similar manner

regardless of their GPA. One can continue to expand this relationship to show that regardless of GPA

students were finding their introductory computer science courses not useful (Figure 13), had minimal

prior experience with MATLAB (Figure 11), wanted one consistent programming language throughout

their education (Figure 17), felt that a computer science class should be initially easy (Figure 15), and

were not comfortable with using MATLAB on their own (Figure 9). In the development of future

introductory classes for computer science these are important aspects to take into account. Regardless

of focus, GPA, or college year, biomedical engineering students on average are not having a positive

experience with how computer science is being taught to them. The discussions brought up throughout

this section need to be reflected upon and used in conjunction with the data of this report to develop

functional approaches for increasing student enrichment and engagement throughout the biomedical

engineering department.

Some shortcomings in the data of this report could reduce its overall impact but can be

explained. One shortcoming occurs just in self-reported nature of all surveys, students are asked to give

honest responses but may induce some bias based upon their own self or any number of a multitude of

other variables. Therefore it is possible that information such as GPA, prerequisite usefulness,

comfortability with MATLAB, and the importance of MATLAB to the students could be artificially high or

low for several entries in this report. However the anonymous nature of this report and its data

collection should have allowed for students to take the time they needed to formulate honest responses

as well as not induce bias based on the students worrying about repercussions based upon their

answers about classes that are being taught currently. Students may have also misunderstood some of

the questions on the survey such as would you have liked one consistent language throughout your

computer science learning, if you are taking a computer science class do you believe it should be easy or hard, and how important do you view MATLAB. Most likely all students understood the questions and any that didn't would have been able to note if they did and their answer for that section would not be included. Also allowing the students to self-report induces the possible error of self-determining values for questions such as how comfortable are you using MATLAB, or if you are taking a computer science class do you believe it should be easy or hard. Self-determining values would mean that one student's idea of being comfortable on a scale from 0-5 could be completely different from another student who feels relatively the same comfortability and thus they would place different answers. The problem also arises for asking if a computer science class should be easy or hard, each student would determine what is easy or hard for themselves and those values would be different between each student's response and be incalculable in this report. This possibility is something that must be taken into account when viewing the results and data of this report, but it should not affect the overall trends determined through the data analysis done within this report as the effects are relatively small.

Conclusions

Biomedical Engineering students; regardless of GPA, biomedical engineering focus, or college year, currently feel that they are not being taught computer science in the most optimal manner. A lack of initial focus on a single computer science language has left students with a weakness in computer science in general and more specifically, in MATLAB. With this weakness teachers have avoided incorporating the subject into classes due to time constraints and student push back. With this negative feedback loop functioning to reduce the amount of MATLAB being taught, and therefore the student's level of understanding, WPI biomedical engineers were being left behind in a world moving forward in utilization of computer science.

It is crucial that steps be made to consistently reinforce computer science learning through its utilization in a multitude of classes across biomedical engineering tracks. This reinforcement must begin with a strong baseline education and introduction into computer science as early as possible in a student's time at WPI. Introducing one language, such as MATLAB, allows for focus to be held upon that specific subject and for it to be utilized by all other courses while also having those courses reinforce the subject. By having this bottom up approach classes could delve much more thoroughly into subjects and increase students understanding utilizing a tool that they learned at the beginning of their education and they are now very familiar with. Utilizing the current curriculum successes at WPI of introducing a MATLAB introductory course for freshmen biomedical engineers, developing a circuit of Alumni or other individuals in industry who utilize MATLAB and could display to students their work and how having this knowledge could allow them to do exciting things would go a long way to increase student interest in the subject. Furthermore properly gauging the difficulty trend of the class would go a long way towards not scaring students off from the subject by having the assignments, tests, or projects that would have jumped beyond even what their hard work could allow them to reach feasibly. The opportunity to use examples that employ real world data while not exceeding the students' abilities would allow for maximum exposure to current methods and models being utilized within industry. These actions would only further prepare WPI's students for the rigors of project based learning and, more importantly, the real world where WPI's engineers could continue to be the paragons for excellence in their respective fields.

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