STEM EDUCATION IN ARMENIA: AN ACTIVE LEARNING CLASSIFICATION STRUCTURE

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WPI

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American University of Armenia

STEM Education in Armenia: An Active Learning Classification Structure

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Abstract

The American University of Armenia (AUA) and STEMGen seek to improve the quality of Science, Technology, Engineering, and Mathematics (STEM) education in Armenian middle- and high-schools, so more students will pursue STEM degrees. We created a classification structure which pairs active learning methods with the verbs of Bloom's taxonomy for a given student learning objective. Implementation of this structure will ease Armenian teachers into using active learning and Bloom's taxonomy in class which will improve the quality of STEM education.

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Authorship

All team members contributed to the editing of every section

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Abstract	Content, grammar, and structure editor	Content, grammar, and structure editor	Lead author
Executive Summary	Lead author	Content, grammar, and structure editor	Content, grammar, and structure editor
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5. Recommendations	Lead author	Content, grammar, and structure editor	Content, grammar, and structure editor
6. Conclusion	Content, grammar, and structure editor	Content, grammar, and structure editor	Lead author

Table of Contents

Table of Figures

Executive Summary

The implementation of Science, Technology, Engineering, and Mathematics (STEM) courses in the education systems has brought success to nations worldwide ranging from economic to social development. Currently, Armenians are facing a low number of skilled workers in STEM-related fields. The cause, partially, is a lack of interest that students have in regards to STEM subjects. When incorporating active learning methods into the classrooms, students become more engaged in STEM subjects, leading them to pursue a higher degree and career in a STEM-related field. The American University of Armenia's (AUA) STEMGen program implements workshops and student programs to help students gain an interest in STEM subjects and help teachers implement active learning methods to engage students. Our goal is to work with the AUA's STEMGen program to help teachers implement active learning methods in the classroom and engage students in STEM subjects.

Project Goals

The STEMGen program focuses on implementing more active learning styles and improving students' interests in STEM careers by training educators to better teach STEM subjects at the middle-and high- school levels. In order to identify successful teaching methods that will help students achieve their learning outcomes, active learning and the use of learning taxonomies such as Bloom's and Structure of the Observed Learning Outcome (SOLO) in the classroom will be beneficial to teachers and students. Active learning is a teaching style where students take a participatory role in lessons and engage in the taught material. Learning taxonomies help teachers determine learning behaviors and student learning outcomes (SLOs).

Our goal for this project is to help our sponsors at the AUA's STEMGen program promote active learning methods to teachers as a way to achieve their desired SLOs. We also aimed to help teachers engage their students in the classroom so that students want to pursue a degree and a career in STEM-related fields that will help Armenia grow as a country. The way that we achieved our goal is by creating a classification structure that pairs creative active learning methods with the different verb levels of Bloom's and SOLO taxonomies. The lower levels in Bloom's taxonomies are *remember, understand, and apply* and the higher levels are *create, evaluate, and analyze*. By pairing various active learning methods with these taxonomy levels, we strive to make it easier for teachers to identify activities through which to engage students in the classroom.

In order to reach our project goals, we achieved five main objectives:

1. Assess the current perspectives of Armenian teachers and middle-and high-schoolers regarding the implementation of active learning in STEM subjects
2. Evaluate the current education system in Armenia pertaining to the knowledge and skills educators currently possess regarding the use of active learning and learning taxonomies in STEM concepts and determine the areas where they can improve
3. Identify additional active learning methods and strategies not referenced in objectives one and two to implement in the future

4. Incorporate active learning methods (referenced in objective three) and how to apply them to Bloom's and SOLO taxonomies
5. Connect active learning and Bloom's and SOLO taxonomies to STEMGen's pre-existing teacher interface

With our five objectives, we discussed active learning methods and learning taxonomies with Worcester Polytechnic Institute (WPI) faculty members, AUA faculty members, and Armenian middle-and high-school teachers. We also captured the perspectives of Armenian middle- and high-school alumni as well as current students. With the use of interviews, surveys, and a literature review, we created our classification structure. The STEMGen program can implement our classification structure into a pre-existing interface that teachers use in order to help students engage in the material.

Methods

By achieving our five objectives, we explored various active learning methods and learning taxonomies as well as analyzed the current STEM education system in Armenia. We first analyzed Armenian teachers and middle- and high-schoolers' perspectives regarding their country's STEM education system and its implementation of active learning. We then analyzed the effectiveness of current STEM education in Armenia as it relates to the use of active learning and learning taxonomies. Our methods consisted of three main strategies: conducting interviews with various groups, distributing surveys to middle- and high-school students in Armenia, and researching lesson plans and rubrics to help with the creation of our classification structure. After collecting data using these three main strategies, we focused on how to connect active learning methods with Bloom's and SOLO taxonomies to create our classification structure.

We conducted interviews with seven WPI faculty members, four AUA faculty members, six Armenian middle- and high-school teachers, and two Armenian school alumni. In the interviews with WPI and AUA faculty members and Armenian teachers we explored different types of active learning methods implemented and the use of Bloom's and SOLO taxonomies. We interviewed WPI faculty members that range from those at the Morgan Learning and Teaching Center, the Interdisciplinary and Global Studies Department, and various professors around campus referred to us by one of our advisors, Aaron Sakulich. We interviewed AUA faculty members such as the Dean of General Education and various professors referred to us by our advisor Norayr Ben Ohanian. We interviewed Armenian public middle- and high-school biology and mathematics teachers referred to us by our sponsors at the AUA. With the Armenian teachers, we needed translators for the interviews who helped us communicate with the teachers. When interviewing WPI and AUA faculty members and Armenian middle- and high-school teachers, we asked them about their experiences with active learning methods and using taxonomies and the advantages and disadvantages of each. We also interviewed Armenian alumni who attended middle- and high-school in Armenia. We were able to interview a student at WPI who is a part of the Armenian Student Association (ASA) and an AUA student. When interviewing Armenian alumni, we identified their perspectives regarding the Armenian education system, how classes are structured, and what they recommend to improve it. With these interviews with the various subgroups, we used these data to understand how beneficial active learning methods in the STEM education system can be.

Our sponsors helped us distribute surveys to current Armenian middle-and high-school students. We conducted surveys to gather a broad range of quantitative data that helped us understand how students feel regarding the current STEM education system. We structured the survey questions to see how satisfied the students are regarding STEM subjects, what STEM subjects interest them the most and least, and the reasoning behind their answers. Our survey questions were mainly Likert scale questions or multiple-choice questions. We had a limited number of open-ended questions due to the amount of time it took to translate the responses. With the use of surveys, we analyzed the data to understand the different perspectives regarding STEM education in Armenia and help us measure the effectiveness of the system in students' engagement and academic performance.

In order to analyze the STEM education system, we researched educational literature such as rubrics, lesson plans, and SLOs. To identify relevant SLOs, we used the Massachusetts Department of Education website to access the *Massachusetts Mathematics Curriculum Framework - 2017* for eleventh-year geometry mathematics. We utilized the *Next Generation Science Standards* as a framework for eighth-year biology courses. With the given frameworks and rubrics that we used, we gathered information such as learning objectives teachers wish to accomplish and implemented it into our classification structure.

Results

In our interviews with the WPI faculty members, we learned about various active learning methods that would be best implemented in classrooms for Armenian teachers. Our interviewees stated that active learning teaching styles encompass various methods and are defined as students staying actively engaged in the material being taught. In addition, active learning involves collaboration with peers, actively asking questions, and students obtaining critical thinking skills. One of our WPI faculty interviewees gave us a helpful article, *226 Active Learning Techniques*, that provided active learning methods that we used in our classification structure. When discussing learning taxonomies with our interviewees, they indicated that they used Bloom more than SOLO. Our interviewees also stated that learning taxonomies are very helpful when creating lesson plans because it makes it easy to classify their SLOs when using the various levels. The AUA faculty members had similar responses to the WPI faculty members when they were asked similar questions.

When we interviewed AUA faculty members about how they implemented active learning methods, they mainly used project-based learning in the classroom. Our interviewees had success when using project-based learning because they would have weekly meetings with their students on the progress of their projects, through which they were able to constantly check students' understandings of the material and see if their students were having trouble with the material. When discussing learning taxonomies, AUA faculty members were familiar with both Bloom's and SOLO but mainly incorporated Bloom's taxonomy in their lesson planning. They stated that Bloom's strength was that it allowed for professors to easily determine the level of learning outcome that they expect from their students at the end of the lesson. After interviewing AUA faculty members, we captured the perspectives of Armenian middle- and high-school teachers and how they implement active learning methods and taxonomies.

When interviewing Armenian middle- and high-school teachers, they explained the importance of how active learning involves a positive relationship between peers and between students and their instructor. Some beneficial active learning methods used were mind mapping and group work that can be used both inside and outside the classroom. Our interviewees stated that it is very difficult to implement active learning teaching styles in classes of over 30 students because it is difficult for teachers to instruct the class as it can become chaotic. What would be best is if class sizes were a smaller size such as 15 students for active learning methods to be successful because teachers can focus more on individual students and easily monitor the classroom. When asked about Bloom's and SOLO taxonomies, teachers were more familiar with Bloom's over SOLO and believed it was beneficial when it came to lesson plans and determining student learning outcomes.

When interviewing Armenian alumni, our interviewees stated that the teaching styles were more conventional, rather than active learning based. They experienced little collaboration with peers and did not do many projects throughout their education, so when entering university, they had to adjust to working in groups and being collaborative with others. Their interest in STEM was piqued by school clubs and programs such as TUMO, a program that offers students an opportunity to learn more and stay engaged in STEM-related subjects. When asked what they would like to see as improvements in the system, they stated that the implementation of cross-classes and smaller class sizes would help students and the education system.

Using our survey, we were able understand the perspectives of about 100 students regarding the Armenian STEM education system. We gained 36 responses from tenth-year students, 28 responses from eighth-year students, 28 responses from ninth-year students, 21 responses from seventh-year students, and 4 responses from eleventh-year students. We identified that in general, students are satisfied with how they are taught STEM concepts. When asked if they wanted to pursue a career in a STEM-related field, many students said "yes" because they liked the subjects. The most popular future occupations that students listed were computer programmer and doctor. When asked how they would like the education system to improve, they wrote that practical experiences, lab experiments, and visual experiences (such as the use of videos) would be beneficial and would help the subjects be taught more clearly.

We used American rubrics to help us analyze the topics that are being taught for eighth-year biology and eleventh-year mathematics. We used the United States *Next Generation Science Standards* and the *Massachusetts Mathematics Curriculum Framework - 2017* to identify subject topics and student learning objectives. In addition, we also used *25 Ways for Teaching Without Talking*, an article given to us by our sponsors and *226 Active Learning Techniques*, an article given to us by a WPI faculty member to implement various active learning methods in our classification structure.

With the help from the two articles and the student learning objectives, we identified in the American standards, we were able to create our classification structure and pair active learning methods with Bloom's taxonomy levels. Our classification structure covered five topics for biology and six for mathematics and each topic included various student learning objectives and suggested active learning methods. We created two Excel workbooks (one for biology and another for mathematics); each spreadsheet in the workbook has one topic and each spreadsheet contains a table for each objective. Each objective used specific verbs that we were able to map to one or more Bloom's levels. With our classification structure, we aim to help teachers implement active learning methods in their classrooms therefore piquing their students' interest in STEM subjects.

Recommendations

Using our classification structure we recommend various ways on how STEMGen can incorporate the classification structure in their pre-existing interface. We also recommend alternative research techniques when continuing this project. We hope that our recommendations will further help Armenian teachers implement active learning methods that will increase student engagement in the classroom.

We first recommend that a broader range of teachers should be interviewed in different STEM subjects, rather than just interviewing biology and mathematics teachers. By interviewing a broader range of teachers, the pre-existing interface can include varying subjects that will benefit more teachers. Second, educators of the same subject should share lesson plans and rubrics to foster collaboration among colleagues. Collaboration among each other will benefit teachers because they can use new ideas in the classroom. This will also improve their teaching skills. Third, there should be interviews with principals of middle- and high-schools. By interviewing principals, this will help researchers get a better understanding of the overall structure of how Armenian middle- and high-schools work and know what administrators think can improve. Fourth, there should be a mentorship between AUA faculty and Armenian public school educators. Many professors implement active learning methods in university courses and they would be able to help public school teachers implement the same methods. Not only will this help the teachers grow as educators, it can help students prepare for university. Fifth, there should be interviews with a more diverse group of Armenian alumni. By interviewing a more diverse group of Armenian alumni, this will help capture all the different aspects of the STEM education system in students' perspectives. Sixth, our sponsors at the STEMGen program collaborate with other STEM programs in Yerevan such as TUMO. This collaboration can help with student engagement and help students gain more knowledge regarding STEM subjects. Seventh, the surveys should contain more open-ended questions. This will allow students the ability to answer questions more in depth with details so that researchers can identify strengths and weaknesses in the education system. Eighth, there should be more time collecting student responses. This will help collect data from more students ranging from different years. And lastly, a variety of rubrics in the United States should be used. We used rubrics and objectives from the Massachusetts curriculum, but looking for rubrics and objectives from other states as well will be beneficial to get an overall understanding on what should be the standard learning objectives for STEM subjects.

Conclusion

We aim for more teachers to implement active learning methods in their classrooms in order to help pique students' interest in STEM subjects. We aimed to achieve our goal of helping teachers reach their desired SLOs through the use of active learning methods and engage their students in the classroom. As students engage in the material and gain interest in STEM subjects, they can go on and pursue a higher degree and career in STEM-related fields. With more skilled workers in STEM fields, Armenia will advance economically and socially. With this, we hope that STEM education will help positively impact Armenia's economic growth.

1. Introduction

As countries strive to participate in the global marketplace, Science, Technology, Engineering, and Mathematics (STEM) education is vital to developing qualified workers who can contribute economically and socially to the STEM-related needs of a country. STEM education helps countries develop and compete at a global level because STEM-related industries provide economic and societal benefits. Economically, STEM improves networks such as transportation, investments, and economic growth rates. STEM's societal impacts include better opportunities for higher-paying jobs and easier global connections between people through the use of personal technologies such as computers and phones. As the benefits of STEM are evident in the development of a country, countries that struggle to prepare their students with the skills and knowledge required for STEM careers fail to capitalize on new opportunities.

According to the Board of Trustees of the American University of Armenia (AUA), Armenian middle- and high-school public schools struggle with preparing teachers to instruct STEM-related subjects. This struggle negatively impacts the achievement of student learning outcomes (SLOs) and can lead to a disengagement of Armenian students in STEM disciplines. This disengagement raises the concern that students will not pursue STEM subjects in post-secondary school. As a result, if fewer individuals pursue a higher degree in STEM, it can hinder the economic aspirations of the country. Due to the current struggles Armenia faces regarding STEM education, the AUA started implementing educational programs that aim to encourage students' interest in STEM education and careers.

The struggle to engage students forms barriers between STEM education and the prospects of furthering the economic development of the country. The causes of this problem include the quality of STEM instruction, the lack of resources to implement hands-on experience in schools, and the lack of understanding that students have regarding STEM career opportunities (Khalatyan, Hajian, & Der Kiureghian, 2019). In response, the Board of Trustees of the AUA alongside the Armenian General Benevolent Union implemented educational improvement programs such as the STEMGen program. The program focuses on more active styles of education, such as hands-on experiences and project work. STEMGen aims to improve students' interests in STEM careers by training educators to better teach STEM subjects at the middle- and high-school levels. STEMGen's programs include a STEM teacher training program, student summer camps, videotaped teacher training workshops, a platform for teachers to access a variety of materials, and test preparation exams (Khalatyan, Hajian, & Der Kiureghian, 2019). As these programs help Armenia take a step towards encouraging active learning in the classroom, there is still a disconnection between the implemented programs and the successful outcomes that active learning can provide.

Active learning and the approach to implement Bloom's and Structure of the Observed Learning Outcome (SOLO) taxonomies will benefit the STEM education system in Armenia by identifying successful teaching methods that will help students achieve their learning outcomes. Active learning is a style of teaching in which students take a participatory role in lessons to foster skills such as critical thinking. It consists of case studies, group projects, demonstrations, and more engagement among students in comparison to a conventional style of teaching. Taxonomies are a type of classification system that evaluates SLOs. With the implementation of active learning and the use of taxonomies such as Bloom's and SOLO, teachers can accurately evaluate their students' success regarding STEM concepts. The use of taxonomies will categorize SLOs to best pair teachers with the appropriate successful active learning methods.

Our goal is to create a classification structure for teachers that will assist the AUA's STEMGen program in promoting active learning to achieve desired student outcomes. The classification structure that we created contains active learning methods that we paired with the different levels of the Bloom's and SOLO taxonomies. This classification structure will further help address the struggles in STEM education experienced by Armenian students. We plan on addressing these struggles such as student engagement through our classification structure that recommends active learning methods. With the new implementation of active learning, we strive to improve teaching outcomes and pique student's interest in STEM.

2. Background

In this chapter, we explore the overall importance of STEM education. By understanding the impact of STEM in other countries, we then compare how the results of these impacts can tackle the current challenges in Armenia. The challenges we examine are students' disengagement in the classroom and the quality of the current teaching styles. To better understand these challenges, we evaluate students' perspectives regarding the country's current STEM education. We further explore how active learning methods can improve the educational system with the use of taxonomies. We conclude by explaining how the AUA, the United States Embassy in Armenia, and the STEMGen program are important stakeholders for this project. These institutions believe that STEM education will help the country compete more economically on a global level and advance as a society. Workers with backgrounds in STEM education can advance the economy and society with the skills they gained that they will later bring to the job market. We will aid in this effort by providing educators in Armenia with a classification structure that provides pairings of active learning outcomes and two taxonomies, Bloom's and SOLO. Based on these pairings, we aim to equip educational professionals at the middle- and high-school level with new active learning methods that will foster their students' growth. Overall, the importance of STEM education and the implementation of active learning to the Armenian curriculum can promote the number of students in STEM careers which in turn will help the country grow economically.

2.1 The Importance of STEM Education

A strong STEM education system helps society achieve sustainable technological growth and stability. The Florida Department of Education (2021) defines STEM education as an approach where real-world lessons are applied to academic concepts that help students cultivate skills such as critical thinking, problem solving, creativity, initiative, teamwork, and more that will help them compete in the ever-growing global economy. Its impact extends from gaining skills in STEM subjects to creating a positive global economic impact. STEM education impacts the lives of many students because it helps them solve problems that focus on real-world issues through collaborations with others. With a greater focus on these subjects in the education system, many more achievements are possible as STEM focuses on innovation and invention that will push young minds to seek further accomplishments and impact the development of their nations.

STEM education is important for teaching young engineers, scientists, and innovators as well as creating a positive impact on developing nations, countries that have an average income lower than ones in industrialized nations (The new dictionary of cultural literacy, 2005). Egypt, for example, faces a problem where their STEM education system is ranked 130 out of 137, according to the Global Competitiveness Reports (Nagdi & Roehrig, 2020). Egypt's problem is similar to the one that Armenia faces, because of its students' low engagement in STEM subjects. A study that observed Egypt's experience with STEM education concludes that after establishing a school that primarily focuses on STEM courses, teachers gained more confidence in teaching STEM subjects. This confidence resulted in professional growth. This professional growth continues to evolve to help students take a bigger interest in STEM. This interest will hopefully result in more students pursuing STEM careers that lead to economic growth in the country (Nagdi & Roehrig, 2020). As in Egypt, STEM education helped other countries advance. India incorporated STEM education in some classrooms through technological engagement such as the use of graphics and videos. Not only has this teaching style improved students' interest in STEM, but it also drove teachers to emphasize the importance of teaching STEM subjects in the classroom using more technological resources such as computers and more active learning methods such as lab-based activities (Tawbush, Stanley, Campbell, & Webb, 2020). As many of these countries conduct studies on only a few institutions that adopted active learning methods for the first time, they do not measure the results that the implementation of active learning in their education system can have on the national scale. Because implementation of active learning continues to change, the result of its implementation in different countries may vary between one another. Similar to countries such as Egypt and India; as Armenia implements STEM-related teaching approaches, student interest and development have the potential to improve. Since STEM has the potential to change student interest in a positive way, STEM also contributes to a country's economy.

Armenia has the opportunity to develop and compete more effectively at a global economic level with the implementation of active learning in the STEM education system. Currently, the country faces low levels of labor productivity in its economic sectors such as the manufacturing industry and transportation, among others, due to the low number of qualified workers in STEM-related careers (Khodzhabekian, 2014). The implementation of STEMGen's programs continues to aid in the introduction of active learning in Armenia's STEM education system as a solution to the problem of labor productivity in Armenia's economic sector. Alongside being a key contributor to Armenia's economic improvements, these programs also lead to the advancement of information technologies (Asbarez, 2020). In order to help with Armenia's economic growth, STEM education contributes to the success of students pursuing STEM-related careers. One of the contributions is through research universities, with graduate-level education and research, where students can accomplish great achievements and discoveries in STEM. The second contribution is through high-schools, programs, and workshops that stimulate creativity. The performance and practical implementation of this creativity aids productivity in the economic market (Rowell, 2013). By developing skills in STEM subjects, students' ability to pursue careers in these sectors will improve and contribute to Armenia's economic development. A way to evaluate the development of these skills is through the assessment of their academic performance.

The assessment of students' academic performance is crucial to evaluate the current educational practices in helping students understand STEM concepts. One indicator of how well Armenian students understand STEM concepts is to compare the students' knowledge base to those of other countries. A study that compares the levels of understanding in math and science is the Trends in International Mathematics and Science Study (TIMSS). Every four years, this study compares fourth and eighth-year students through a globally standardized test. These grade ranges map to primary and basic schools in the Armenian education system. In 2019, Armenian fourth-year students scored 498 on mathematical achievement and 466 on scientific achievement. These scores are slightly lower and significantly lower than the studies' center point of 500 respectively. NCES calculated this center point by using the mean score from all participating countries that took the first TIMSS in 1995. These scores indicate Armenian students are less proficient in math and science when compared to their international counterparts. Based on the TIMSS, Armenian students placed 35th and 43rd out of the 57 participating countries in math and science respectively. While data are unavailable for the 2019 Armenian eighth-year results, in 2015 the Armenian eighth-year students scored 481 in math achievement and 444 in science achievement (Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B., 2019). Since Armenia began participating in TIMSS in 2003, the study provides information to internationally evaluate the country’s general education system as well as comparing teaching methods and acknowledge problems in the country’s curricula (Armenia. Ministry of Education and Science, 2014). In order to improve academic performance in the STEM education system, the Armenian government looks to reform their current system and teaching practices.

2.2 Current State of STEM Education in Armenia

The Armenian Ministry of Education and Science began reform in order to move away from the conventional style of teaching to a more active learning style of teaching. The conventional teaching styles are teacher-centered rather than group activity-based and focus on the memorization of material rather than active participation (Balasanyan, 2017). In the structure of the Armenian education system, various class years still use this conventional style of teaching in their classrooms.

The structure of Armenia’s education system ranges over class years that map to K-12 in the American education system and are separated stages. These class years consist of three main stages: pre-school, general education, and post-secondary school. General education is an umbrella term encompassing three more distinct levels of schooling that are primary school, basic (middle) school, and high-school. These levels correspond to first through fourth grade, fifth through ninth grade, and tenth through twelfth grade, respectively. There is a need for improvement in the overall education system due to the low retention rate of students after the completion of the three main branches.

Armenia currently faces concerns such as low enrollment in high-school. After basic school, the high-school dropout rate is around 15% (Armenia. Ministry of Education and Science, 2014). Around 10% of Armenian students attend vocational schools after completing basic school which partially contributes to the low rates of high-school enrollment. An example of a vocational school in Armenia is a two-year institution that high-school level students can attend in order to learn skills for professions such as being a plumber, electrician, receptionist, etc. (Our Lady of Armenia, n.d). While combined enrollment between the vocational and secondary school is about 95% after basic school, a majority of students who attend vocational schools will not go onto higher level education such as attending post-secondary school and will instead join the workforce of the occupation they studied. Due to the low retention rates in secondary school, Armenia’s policymakers continue to review areas for improvement. The introduction of an active learning framework is one way that can promote the country’s success.

Armenia’s Ministry of Education continues to introduce the concept of active learning in their new STEM education curriculum that steers away from the conventional style of teaching. The introduction of active learning in Armenia issued the creation of STEMGen, a three-year program that introduces STEM education to the Armenian youth. The AUA created the STEMGen program in hopes that it can pique student interest in pursuing a career in STEM. The program also aims to help challenge students by stimulating their creativity, critical thinking, and communication skills, among others (Asbarez, 2020). The STEMGen program also trains teachers to have a higher level of understanding of STEM concepts. This understanding results in better instruction of STEM subjects for middle- and high-schoolers (Asbarez, 2020). Alongside implementing a new curriculum containing active learning, in 1996, Armenia signed a Partnership and Cooperation Agreement with the European Union (Terzian, 2015). With this agreement, Armenia planned to reform its educational system to align more with European Union teaching styles with open practices, more modern and technology-driven based practices. Armenia agreed to this pact to help the country emphasize information and communication technology which promotes STEM education (Terzian, 2015). Furthermore, in 2003, the country joined UNESCO's Education for All movement (EFA) and focused education reform efforts around meeting EFA's six primary goals by 2015 (Yi, 2016). These goals include the expansion of early childhood education, free primary education for all students, and a 50% adulthood literacy rate increase, among other equality-focused objectives (UNESCO, 2000). Armenia either achieved or put in place measures to achieve a majority of the EFA's goals such as the previously mentioned equality-focused objectives: gender parity and equality in education (Armenia. Ministry of Education and Science, 2014). As Armenia attempts to improve its STEM education, a transition to active learning in the classroom will help engage students with the material their instructors teach.

2.3 Active Learning in Educational Settings

Active learning focuses on engaging individual students with the content and with peers opposed to conventional learning by passively listening to their instructor. Di Biase (2009) references Yoram Haroaz (2005), the head of the principals' training department in Beit Belr College in Israel, "traditional (sic) schooling relies on four aspects: Learning is listening; teaching is telling; knowledge is an object; and to be educated is to know valuable content." An issue with conventional teaching is it leads to very surface-level understanding (Ueckert & Gess-Newsome, 2008). This type of understanding does not allow students to have a deeper connection with the learned material. For example, conventional styles of teaching leave few chances for independent thought while active learning promotes an active and engaged mind by involving processes such as assimilation, adaptation, and interpretation (Di Biase, 2009). Active learning allows students to engage with the material by debating ideas, asking questions, and building upon using prior knowledge for a deeper understanding. By engaging with the material, students construct their own understanding and interpret ideas based on their own experiences (Ueckert & Gess-Newsome, 2008). While the successful shift to active learning proves beneficial to classrooms, there can also be drawbacks.

The atmosphere of a student's classroom is vital in creating either a rewarding or harmful effect on students. Without the right atmosphere, students can start to experience anxiety resulting in lower retention rates and the adoption of adaptive and/or maladaptive coping mechanisms (Brigati, England, & Schussler, 2020). Some adaptive mechanisms that foster learning are asking questions, talking to peers, and problem-solving. However, some maladaptive mechanisms are avoiding eye contact with the teacher, not raising their hands, and answering quickly to avoid attention (Brigati, England, & Schussler, 2020). These mechanisms emphasize the need for the right established environment. Student-teacher relationships will improve if conditions are fair and consistent (Di Biase, 2009). Students will understand that mistakes are a part of learning and they will feel safer taking risks. A greater social environment amongst students will result in valuable collaborative work. This value comes from the challenges and the encouragement active learning provides students to think critically as opposed to just reproducing facts given to them. As we will show, the successful implementation of active learning made a positive impact in other countries.

In recent years, many countries such as Thailand, Ethiopia, and Uganda started adopting more active learning reforms in some of their schools to increase the quality of teaching and students' understanding of new information. These reforms have led to a change in the education systems. For example, in Thailand, as teachers became more familiar with the reform to active learning, it was easier for each instructor to adopt these new practices and make changes in their own teaching (Di Biase, 2009**)**. Some schools in Ethiopia, Uganda, and Maldives also adopted the idea of active learning. Rather than focusing on the students' outcomes, these countries focused more on the social and emotional relationship between students and teachers. These nations' teachers moved away from the conventional teacher role to have a more supportive relationship with their students. This resulted in a better quality of both teaching and learning. A Nepali teaching hospital implemented active learning and saw an increase in student participation. Teachers incorporated questions, discussions, and cases more into their classrooms (Mehanni, Wong, Acharya, Agrawal, Aryal, & Basnet, 2019). Instructors received feedback from their students that allowed for behavioral changes in both the students and teachers. The intention of these evaluations was to have students realize the importance of their participation (Mehanni, Wong, Acharya, Agrawal, Aryal, & Basnet, 2019). Teachers adapted their teachings based on the feedback and students also had a more active role in the classroom. To reap the benefits of this teaching style, teachers need the necessary training to transition to active learning.

Initiatives that promote active learning require a major change in the pedagogical behavior of educators. This change is a shift from conventional teaching styles to active learning styles. Teacher engagement and guidance through this transition will help with the implementation of active learning. This guidance can be through training and technical support for the teachers. Before training teachers with techniques on how to engage with active learning methods, teachers should understand the reasons behind the adoption of such methods and the need for their implementation (Di Biase, 2009). The reasons include improving their quality of teaching and helping their students engage more in the subject matter. By understanding these reasons, teachers will be more open to this shift. During this training, teachers need to first build their skill bases to implement active learning. If they have this skill base, they can easily "expand their teaching repertoire and develop a clear framework of how and when to effectively use the new teaching strategies" (Di Biase, 2009**)**. Educators can build their skill base by gaining a conceptual understanding of why group work among student learners matters. Participatory training provides the demonstration and discussion of this pedagogical knowledge needed to foster a better connection between theory and practice. The reform to active learning does not stop at the end of the training programs, this is a constant and continuous effort with the school and the teachers to implement active learning in the classroom. Overall, established key concepts and steps are important for a smooth transition to active learning. The use of Bloom's and SOLO taxonomies will also aid in a successful transition.

2.4 Bloom's and SOLO Taxonomies

Teachers can evaluate the quality of work their students produce and whether they achieve their learning outcomes with the use of taxonomies. The primary goal of using a taxonomy with active learning is to identify the knowledge, skills, and abilities that students acquire. Taxonomies can also help with supporting the design of the curriculum and align learning goals with activities. There are various taxonomies such as Bloom's and SOLO but the use of either taxonomy will depend on the criteria the instructor wants to use. Instructors can use Bloom's taxonomy to develop lesson plans based on its different cognitive levels.

Bloom's taxonomy is a tool to develop and build lesson plans that have structure, a goal, and learning process parameters (Pikhart & Klimova, 2019). Dr. Benjamin Bloom, a college examiner who modified educational requirements and assessments at the University of Chicago, helped create Bloom's taxonomy. There are two different versions of this taxonomy. One is the original version from 1956 and a revised version from 2001 that retained most of the original taxonomy, but is more refined and introduces new concepts. This classification system can help teachers categorize their students' learning outcomes using six basic levels. The organization of these levels of acquired skills is in a hierarchy starting at lower-order cognitive skills such as *remember* and *understand* to higher-order skills such as *apply, analyze, evaluate,* and *create*. Figure 1 shows the hierarchy of these levels. Another type of frequently used taxonomy is SOLO taxonomy that classifies students' responses by complexity and maturity.

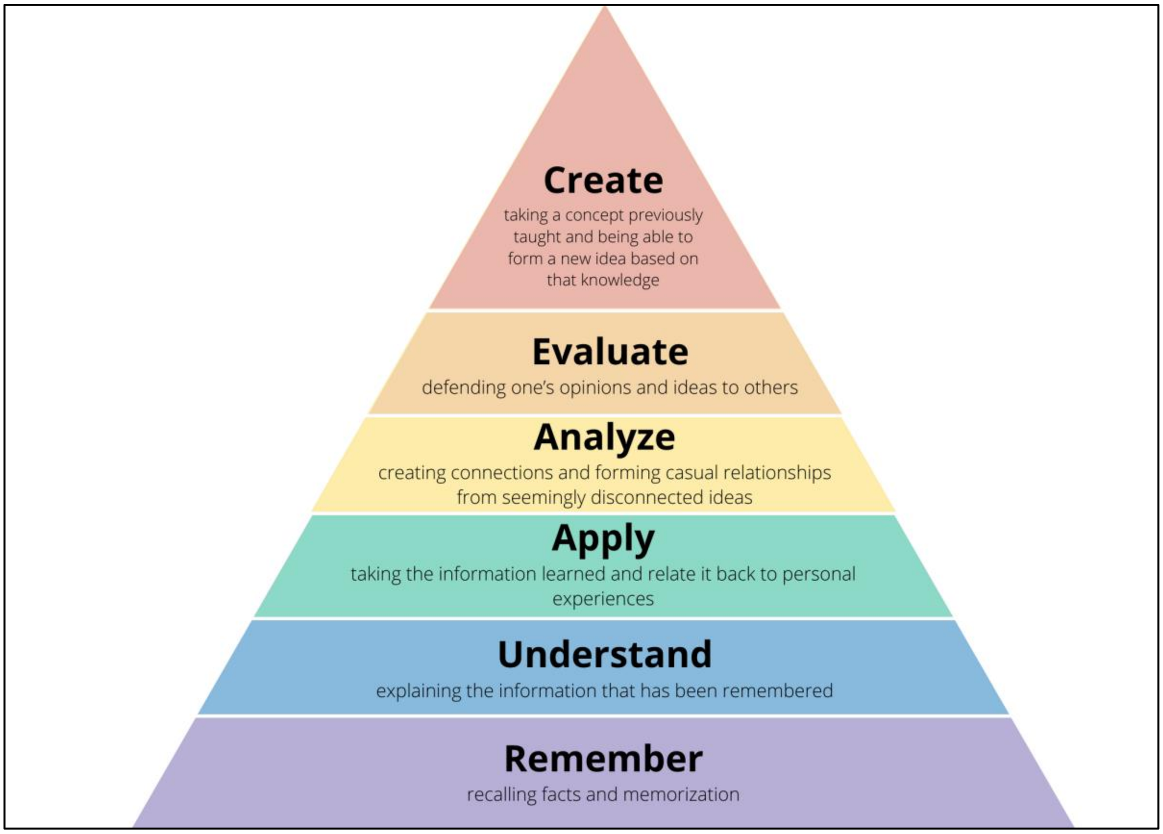

Figure 1: The different levels of Bloom (based on Bloom (2001))

John Biggs and Kevin Collis created SOLO taxonomy, which is an alternative to Bloom's. SOLO taxonomy is a criteria-based framework that ranks learning on different levels based on maturity and complexity. The structure of this taxonomy is in five levels: *pre-structural*, *uni-structural*, *multi-structural*, *relational*, and *extended abstract*. A student can provide a response that refers to the *pre-structural* level corresponding to the least mature response to the *extended abstract* level corresponding to the most mature response. Biggs and Collis developed this model under the assumption that the student uses one of the three different concepts: *irrelevant concepts*, r*elevant concepts explicitly taught*, and *relevant concepts not explicitly taught*. Figure 2 shows the relationships between these levels and concepts. A student's learning is more mature if they can respond with outcomes that are relevant and not explicitly taught (Sprecher, 2019). By utilizing both Bloom's and SOLO taxonomies, teachers need to be aware of the benefits and the shortcomings of both.

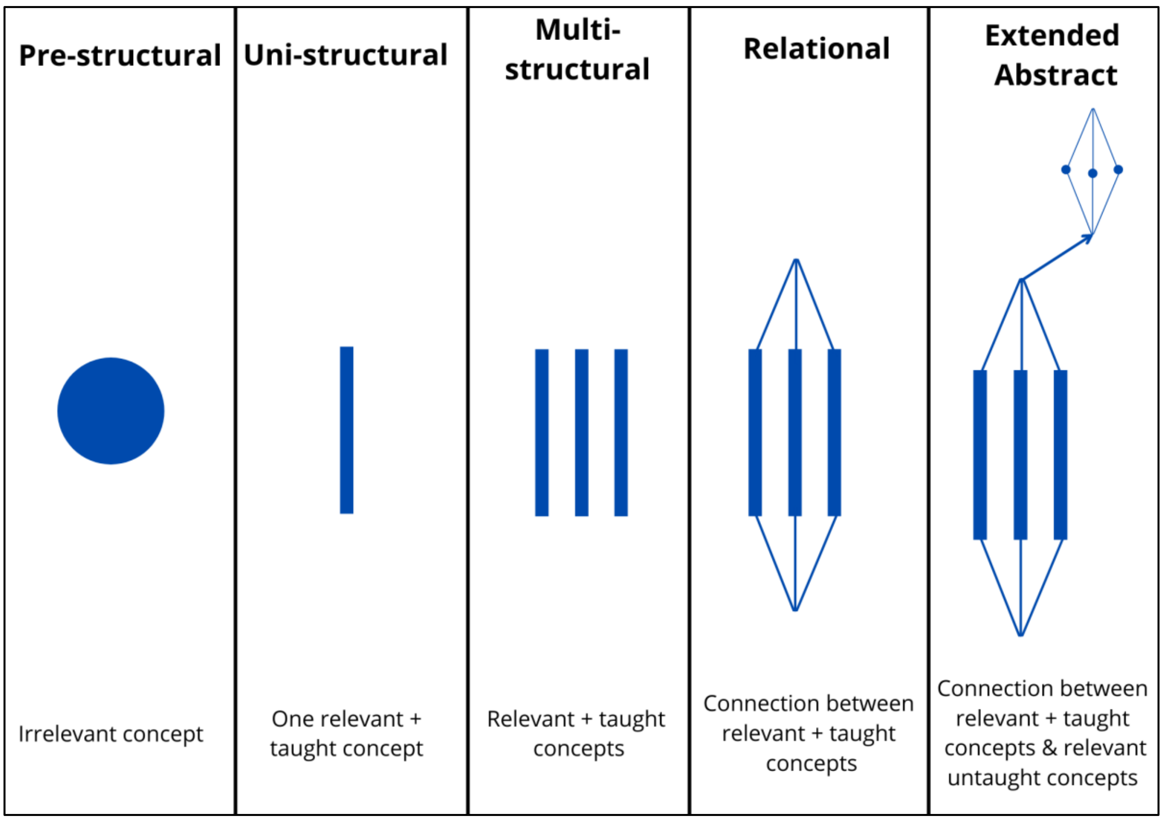

Figure 2: The five different structural levels and the concepts of SOLO taxonomy (based on SOLO (1982))

Both taxonomies have their advantages and disadvantages. Bloom's taxonomy is a helpful evaluation tool for describing the cognitive skills required to attain particular student learning outcomes. For example, a teacher can write an example question either based on a lower Bloom level such as having the student write a definition, or task them with something more complex such as interpreting evidence (Stanny, 2016). However, one complication of Bloom's taxonomy is its ambiguity. This framework has a flexible hierarchy with overlapping categories, focusing more on the teacher's discretion on how they want to classify their students' learning objectives (Seaman 2011). Since Bloom's taxonomy is a verb-based framework, certain verbs known as ‘cue words’ associated with a lower level in Bloom’s taxonomy in one context can correspond with a higher level in another context (Stanny, 2016). In addition, a verb can have multiple meanings. For example, *rewrite* (meaning to write again) could correspond to a low level such as copy or transcribe or a high level such as revise or edit (Stanny, 2016). As Bloom’s taxonomy has its advantages and disadvantages, SOLO also has benefits and drawbacks.

SOLO has strengths and weaknesses. SOLO taxonomy allows a consistent understanding of maturity from an educator’s perspective. However, the use of SOLO cannot categorize all tasks given to students. For example, it is not possible to demonstrate an abstract level of learning on multiple-choice quizzes (Sprecher, 2019). As both Bloom’s and SOLO taxonomies provide help and insight to the education system, Armenia’s education system can utilize the two taxonomies to overcome the obstacles the country faces. The implementation of both taxonomies will impact primary stakeholders by the overall reform of the education system.

2.5 Impacted Stakeholders

The primary stakeholders for this project are Armenian teachers in middle- and high-school and their students. In addition, the AUA and the US Embassy in Armenia are also stakeholders because they invested time and funds into STEMGen’s success. Lastly, the AUA’s branch program STEMGen is a stakeholder as well. The Armenian teachers and students will directly benefit from the project as they use the classification structure to improve their teaching methods.

This project will impact teachers in many ways but the overall goal is to improve their ability to teach STEM concepts. The classification structure we created contains several active learning methods determined, through our research, to be the best for students to meet the expected learning outcomes. Teachers will use the classification structure to select the learning outcomes and overall objectives. We then provided them with suggested active learning methods to have their students meet those outcomes. As the classification structure impacts teachers and students, the AUA will also benefit from the project because an improved education system can lead students to pursue a higher education. Hopefully, after post-secondary school, these students will pursue STEM careers fulfilling the need for qualified workers in those sectors. The remaining impacted stakeholders, the AUA and STEMGen will assist in the development of the classification structure.

The AUA is the sponsor of the project and the university began pursuing the problem at hand after contact with the U.S. Embassy in Armenia. AUA’s involvement in the project is through STEMGen. STEMGen’s primary method of solving the previously stated issues is to increase the education of teachers in STEM concepts as well as provide them a variety of teaching methods. STEMGen tackled this problem through a number of workshops held in 2020. Aside from holding workshops focused on teacher training, STEMGen develops lesson plans and rubrics to assist teachers in STEM education topics. Our classification system will make it easier for users to navigate STEMGen’s interface and give them suggested active learning methods.

2.6 Conclusion

As Armenia looks into active learning methods to help their country develop, STEM education is a key factor for the country's growth. Transitioning from conventional teaching styles to a more active learning approach can encourage more students to go into STEM-related careers that can benefit the country overall. As Armenian teachers try to look for a more engaging approach in teaching, they have certain objectives and outcomes for their students. The use of Bloom's and SOLO taxonomies can help classify these objectives and outcomes. With these classifications, we will suggest active learning methods for teachers to incorporate in their classrooms. Our project recommends active learning methods to achieve the desired student learning outcomes that can help improve the education system as a whole.

3. Methodology

The goal of our project is to create a classification structure with recommended active learning methods. Our classification structure builds upon STEMGen's current teacher interface. The AUA faculty members developed this interface for teachers to find and post materials such as lesson plans, worksheets, and rubrics. This project will better equip teachers with resources that will improve their teaching styles and meet the different educational needs of their students. Our project will complement STEMGen's interface by recommending methods that teachers can use based on desired SLOs. These methods in turn will encourage Armenian students to pursue higher education and careers in STEM that will help the country progress economically.

To achieve this goal, we accomplished five main objectives:

1. Assess the current perspectives of Armenian teachers and middle-and high-schoolers regarding the implementation of active learning in STEM subjects
2. Evaluate the current education system in Armenia pertaining to the knowledge and skills educators currently possess regarding the use of active learning and learning taxonomies in STEM concepts and determine the areas where they can improve
3. Identify additional active learning methods and strategies not referenced in objectives one and two to implement in the future
4. Incorporate active learning methods (referenced in objective three) and how to apply them to Bloom's and SOLO taxonomies
5. Connect active learning and Bloom's and SOLO taxonomies to STEMGen's pre-existing teacher interface

After we accomplished these five objectives, we recommended a classification structure that will help teachers match the desired SLOs with the best active learning methods. In this chapter we justified our objectives, went into detail about how we collected data to achieve our objectives, clarified how we analyzed these data, and lastly explained how we created our classification structure.

3.1 Objectives

We analyzed Armenian teachers and middle- and high-schoolers' perspectives regarding their country's current STEM education system and its implementation of active learning. In this phase of the research, we identified their viewpoints and the reasons behind those viewpoints. We also explored if these perspectives influenced the students' interests in pursuing higher education and a career in STEM. As we understood the context for these viewpoints, we started to evaluate the use of active learning and learning taxonomies in the current Armenian STEM education system.

We analyzed the effectiveness of current STEM education in Armenia as it relates to the use of active learning and learning taxonomies. We determined this effectiveness by comparing the performance of Armenian students in STEM to their international peers as well as the country's standards. With this analysis, we established a rationale behind the transition from the current conventional teaching style in STEM subjects to active learning. Alongside this rationale, completing this objective helped us document strengths and weaknesses regarding the current education system in Armenia. To help improve this system, we identified effective active learning strategies.

We explored successful active learning methods that the STEMGen program can implement. This objective helped us compare active learning methods in other countries to Armenia's current teaching style and focus on its relative strengths and weaknesses. This information provided insight on what active learning is, what methods educators deem successful, and the disadvantages and advantages of using these methods. This information also helped us verify that the information gathered about active learning in the background chapter extends to Armenia. In addition to identifying active learning methods, we also researched learning taxonomies to better understand the teaching process.

We learned about two taxonomies, Bloom's and SOLO and how effective they are when it comes to teachers evaluating their students' success. In addition, we expanded on the benefits and downsides of using these taxonomies within the context of active learning. This allowed us to categorize lesson plans, rubrics, and more within the various levels of Bloom's and SOLO taxonomies for our classification structure. We used the information gathered regarding active learning and these learning taxonomies to help create our classification structure.

The final objective focused on how to best connect active learning methods with Bloom's and SOLO taxonomies into a classification structure for STEMGen's interface. We aimed to help educators with the transition to active learning in STEM subjects. We also aimed to better equip these instructors with active learning teaching methods to engage their students more with the material to achieve the desired learning outcomes. In order to obtain the necessary information needed to complete our objectives, we employed various methods of data collection.

3.2 Data Collection

We used a common strategy for our interviews, surveys, and the use of case studies to gather data (Fig. 3). We interviewed WPI faculty members to collect information on how they successfully implemented active learning methods and to elaborate more on Bloom's and SOLO taxonomies. We interviewed Armenian teachers and AUA faculty members to better understand the current education system, and how they use active learning and Bloom's and SOLO taxonomies in their own classrooms. Lastly, we interviewed Armenian school alumni to elaborate on their experience and make recommendations to improve the system. Based on a meeting with our sponsor, we created and distributed surveys to current Armenian students. We gathered American lesson plans, rubrics, and student learning to use in our classification structure. As we started our data collection, we realized that conducting interviews was the biggest contribution to our information gathering process.

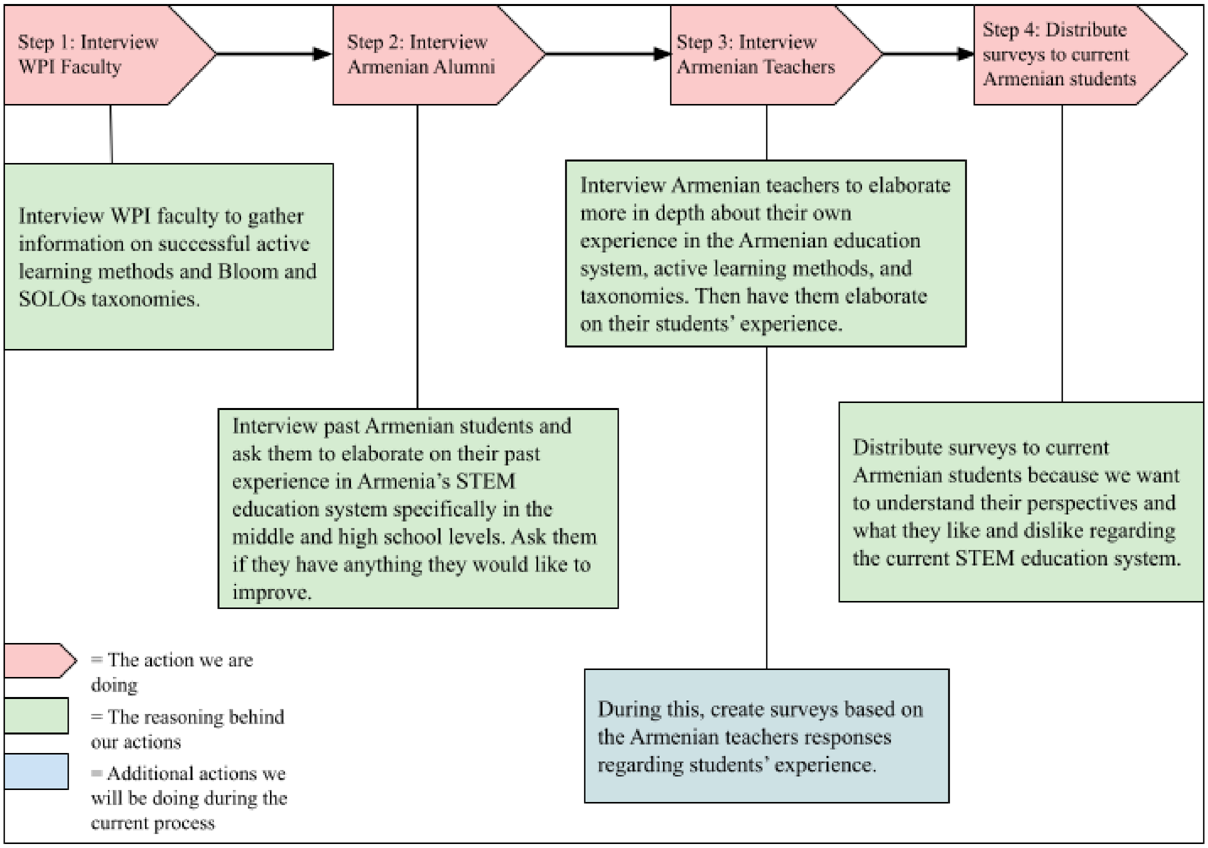

Figure 3: Our approach to conducting interviews and distributing surveys

3.3 Interviews

Conducting interviews was an essential component of our data collection because we were able to obtain important information that helped with the creation of the classification structure. These interviews started off with WPI faculty members from the Morgan Teaching and Learning Center, then Armenian middle- and high-school alumni, and lastly Armenian middle- and high-school teachers. Interviews were the easiest way to gain information since we asked open-ended questions that led the participant to reveal more insights than if they answered on a survey. In addition, we asked questions that stemmed from a certain response or asked the interviewee to elaborate on a point they made. We chose interviews over email because communication via email would prove to be difficult. It would be difficult since email responses could vary in time from a few hours to a few days. However, interviews took time to conduct and they required us to allocate time to organize and analyze our notes. With these interviews, we gathered different perspectives on STEM education, successful active learning methods, and Bloom's and SOLO taxonomies. Due to the COVID-19 pandemic, we did all interviews through Zoom following our interview protocol.

Our interview protocol consisted of two team members taking notes. One member was the primary note taker and the other team member was the secondary note taker. They compared notes after the interview. The third team member was the facilitator of the interview and rotated asking questions with the secondary note taker. At the start of the interview, we asked the interviewee for their consent to record the interview as well as use any helpful information they gave us in our "Results" section of our final report. As we began the interviewing process, we first interviewed WPI faculty members.

We interviewed WPI faculty members about active learning and learning taxonomies. In our interviews, we asked about their experience with active learning and their implementation of it in the classroom. We linked the theory about active learning regarding implementation and the pros and cons described in the background chapter with practice. We interviewed faculty and staff members in the Morgan Learning and Teaching Center such as Dr. Chrysanthe Demetry, the center's director, and Dr. Kimberly LeChasseur, the center's research and evaluation associate. In addition to asking WPI faculty members about active learning, we interviewed them about both Bloom's and SOLO taxonomies. We asked if and how they utilized one or both of these taxonomies when they design lesson plans and worksheets to have their students achieve their students' learning outcomes. We also asked them to evaluate the effectiveness of both. By elaborating on their evaluation, we asked them to describe strengths and weaknesses of using Bloom's and/or SOLO. In addition to interviewing WPI faculty members about active learning and these taxonomies, we also interviewed Armenian teachers regarding these topics and their country's current education system.

We interviewed the Armenian teachers to understand their current perspectives on the STEM education system in Armenia, their knowledge regarding active learning methods and taxonomies, and their students' learning outcomes. We conducted interviews with AUA faculty members such as our advisor Norayr Ben Ohanian and selected teachers referred to us by our sponsor, the AUA. In addition to our team, an Armenian university student (recommended by the AUA) was on the Zoom call to translate, if necessary. The teachers' experiences gave us a better understanding of how they assess their students' learning outcomes using taxonomies. We also asked them about what features they would like to see in our classification structure. Along with asking Armenian teachers their viewpoints of the STEM education system, we asked Armenian middle- and high-school alumni about their thoughts and experiences within this education system.

We conducted interviews with students who have experience attending middle- and high-school in Armenia to identify their perspectives regarding the Armenian education system. We recruited a student at WPI that is a part of the Armenian Student Association (ASA) as well as a current student who attends the AUA. We asked them to elaborate on their past experiences and if they had any recommendations on how the teaching of STEM concepts can improve. We learned if they had an interest in STEM while attending school in Armenia, if the teaching methods used by teachers helped them stay engaged in the STEM subject, if they could identify strong and weak areas in the STEM education system, and if they had any recommendations to improve it. By interviewing Armenian alumni, we gained insight on how students perceive current teaching methods and if they believed their teachers had an effect on the student's desire to study STEM subjects. Alongside interviews with WPI faculty members, Armenian teachers, and Armenian alumni, we administered surveys to current students in Armenia and evaluated their perspectives on the current education system.

3.4 Surveys

We conducted surveys to gather a broad range of quantitative data that helped us understand how students feel regarding the current STEM education system. We created survey questions with the help of our sponsors. We structured the survey questions to see how satisfied the students are regarding STEM subjects, what STEM subjects interest them the most and least, and the reasoning behind their answers. This survey gave us an opportunity to evaluate students' knowledge on STEM concepts, their experiences within the classroom, and if their experience had an impact on their academic performance. We provided our sponsors with surveys that they distributed to middle- and high-school students. Since we needed information such as lesson plans that could not be obtained through interviews or surveys, we performed a literature review to obtain these documents.

3.5 Literature Review

We worked with our sponsors to gather active learning resources that they would like to see incorporated into the classification structure. Due to the seven-week time frame, we focused our initial data collection on American eighth-year biology and eleventh-year mathematics. Using the Massachusetts Department of Education website, we collected course frameworks, which include SLOs for middle- and high-school mathematics courses. Specifically, we used the *Massachusetts Mathematics Curriculum Framework - 2017* for geometry for eleventh-year mathematics. We used the *Next Generation Science Standards* for eighth-year biology. We utilized these resources to assess the current teaching methods. We gathered information from learning objectives given to teachers and designed our classification structure around the current frameworks. Through the evaluation of the current education system, we identified effective and ineffective parts of the system in regards to students achieving their learning outcomes. Using data gathered through our literature review, prior interviews, and surveys, we started to process and analyze the collected data.

3.6 Analysis

We used the data found in case studies research, surveys, and interviews to develop our classification structure. These data helped us recommend active learning methods to Armenian educators that they can implement in their classrooms. Survey responses helped us get an overall understanding of current perspectives related to the Armenian education system. The interviews assisted us to interpret teachers' experiences regarding active learning implementation and taxonomies. Lastly, continued research with the use of online databases helped us gather an overall understanding of the various topics related to the project. With the information collected and analyzed in previous sections, we came up with a classification structure that will help teachers connect active learning methods with their desired students' learning outcomes. We started by analyzing the data collected from our interviews.

After conducting interviews with WPI faculty members, Armenian teachers, and Armenian alumni, we collected qualitative data. With these data, we performed inductive coding. Erika Yi (2018) defines inductive coding as building research from scratch based on the data collected. As we gathered responses from these interviews, we categorized them in themes. These themes fit under either active learning or information regarding taxonomies. We organized our interview data and separated them into themes by having at least two different note takers during the interviews. We then compared notes to identify important information that helped with the pairings in our classification structure. We used themes listed in the background chapter, such as the current implementation of active learning, the use of Bloom's and SOLO, the advantages and disadvantages of each taxonomy, etc. These themes helped us pinpoint how the two different taxonomies can categorize student learning objectives, the current methods practiced in Armenia, and the problems and successes the Armenian teachers are facing with active learning. In addition to gaining insights from our interviews, we also analyzed the survey data we received from current Armenian students to help us reach our objectives.

From the surveys, we analyzed the Armenian students' perspectives of their educational system. Our sponsors translated our surveys to Armenian and handed them out to students in levels seven through twelve. We limited questions that require written responses because translating each response to English would be very time-consuming. It was also possible that some words could get lost in translation. We determined areas in the STEM education system that students feel are in need of improvement. We assessed the factors that contribute to these viewpoints. By pinpointing the positives, we better paired teachers with methods that students are likely to enjoy and engage with. By identifying the negatives, we found areas in the current instruction that need improvement. Using a Likert scale in our surveys, we were able to find an average answer regarding if the education system made a positive or negative impact on students' lives. Since we limited the number of open-ended questions, we determined if a majority of those taking the survey agree or disagree on the same topics, or if there was a broad range of different opinions. For example, a majority of students might have agreed that a certain aspect such as lesson plans or a specific subject needs improvement. We used this knowledge to pair strategies that focused on that specific problem. We analyzed the data to understand the different perspectives regarding STEM education in Armenia and help us measure the effectiveness of the system in students' engagement and academic performance. To further analyze the STEM education system from an educators' perspective, we analyzed the data we gained from the literature review.

We analyzed the collected data in regards to current rubrics, lesson plans, SLOs, and student performance in STEM subjects in America. We compared rubrics by looking at what each rubric considers beyond expectations, meeting expectations, and below expectations in regards to student knowledge and/or level of work. We also explored which active learning methods would best improve the quality of STEM education. By collecting notes from case studies on how others categorized certain levels of Bloom's and SOLO, we had a larger scope of knowledge on how to categorize activities and lesson plans. Case studies filled in any remaining gaps of information regarding categorizing student learning outcomes to the aforementioned taxonomies that our interviews could not provide. Unfortunately, these might not be as applicable to an Armenian context as the insights that the country's educators would have. With the assessment of Bloom's and SOLO taxonomies, we implemented a classification structure that pairs teachers with suggested active learning methods.

3.7 Development of the Classification Structure

We reanalyzed the data from interviews, surveys, and studies to establish a foundation of successful active learning methods. Based on the information learned in our third objective, we began making a classification structure that pairs specific active learning methods to types of student learning outcomes. We categorized the student learning outcomes into the different levels defined in Bloom's and SOLO taxonomies which we learned about when we explored in our fourth objective. We then incorporated these pairings into a classification structure for STEMGen's pre-existing teacher interface. This classification structure will allow teachers to search keywords regarding learning outcomes and recommend the best active learning methods to them as they teach STEM subjects in their classroom.

4. Results

We started off by interviewing seven WPI faculty members, four AUA faculty members, six Armenian middle- and high-school teachers, and two Armenian school alumni. From interviewing WPI and AUA faculty members and Armenian teachers, we learned about the implementation of active learning methods in the classroom and the advantages and disadvantages that result from their implementation. We also learned about how WPI faculty members and Armenian educators incorporate Bloom's and SOLO taxonomies in their lesson plans as well as how they use them to assess their student learning outcomes. Lastly, we learned that although there are benefits when it comes to implementing these taxonomies, there are also drawbacks. In addition, we asked these Armenian professors and middle- and high-school teachers to elaborate on the methods they implement to engage their students and how it impacts their teaching. After that, we interviewed the alumni and discussed their experiences in the Armenian education system regarding the teaching styles used in the middle- and high-school STEM courses. We also asked for any ideas that they had that would help improve the education system for future students and teachers. We then distributed surveys to students who are attending Armenian middle-and high-schools. After distributing the surveys, we analyzed the trends that we found from the current students in Armenia and their perspectives regarding STEM courses. We later analyzed lesson plans and rubrics specifically for two subjects, eighth-year biology and eleventh-year mathematics. Finally, we created a classification structure based on the information we learned throughout the course of our research regarding active learning methods and taxonomies.

4.1 WPI Faculty Interviews

We started our data collection by asking WPI faculty members about their overall perspectives regarding active learning and how they used active learning methods in the classroom. We asked them to evaluate these methods by having them identify the benefits and drawbacks. For the second portion of the interview, we asked them questions regarding Bloom's and SOLO taxonomies. We asked them how they used these taxonomies when creating lesson plans. In addition to asking about active learning methods, we asked them to identify the advantages and disadvantages of these learning taxonomies. We first asked our interviewees what experience they had in teaching and if they could define active learning in their own words.

We asked our seven interviewees their definition of active learning and they had very similar responses. Most of our interviewees explained that active learning is not just a specific technique or activity, but it encompasses a large range of methods. They confirmed the research we discussed in the background chapter. They defined active learning as the engagement of students with the material and not just passively listening while their teacher lectures. Active learning involves students making decisions, asking questions, and collaborating with their peers. They also mentioned that active learning builds on students' pre-existing knowledge and helps them with critical thinking skills and problem-solving. After we understood how WPI faculty members define active learning, we inquired about their familiarity with implementing active learning in their classrooms.

We asked WPI faculty members about their experiences with practicing active learning in the classroom and the methods they deemed successful. The majority of our interviewees said instructors can implement active learning in any STEM course, and it's not subject-specific. However, there are some fields in which it is easier to implement active learning than others. For example, subjects that can incorporate labs, such as chemistry and biology, can incorporate hands-on experiences more easily than a subject like mathematics. Most of our interviewees also stated that it was hard at first to implement this type of teaching style because they did not learn this way when they were students. In addition, they stressed that it takes time to successfully implement active learning. Most of our interviewees started introducing active learning slowly into their classrooms, first with a few methods and then implementing more as they got more comfortable. This helped give both the instructors and the students a smooth transition towards the use of active learning. Lecturing is unavoidable, but there are still ways to implement active learning in the classroom. A few methods that our interviewees utilized were think-pair-share or having students take polls in the classroom. These methods require students to think about concepts their instructors taught and apply the concepts they learned. Think-pair-share also allows students to talk to their peers to discuss answers and their thought processes, which makes students more confident in their answers when the instructor calls on them. Based on their experiences with the implementation of active learning, we asked our interviewees the advantages and disadvantages of these methods.

Our interviewees identified the benefits that they noticed when implementing active learning. They stated that they were unsure if they noticed the use of the active learning methods directly correlated to their students' academic performance. However, they did see students gain self-efficacy and confidence with the use of active learning methods. One of these methods is collaborative team projects, which is a great method to boost student confidence. This method also helps build a community for students and improves peer-to-peer relationships. These assignments incorporate team-based learning, allowing team members to learn from each other and work together to complete their projects. These types of assignments are another opportunity for students to apply the knowledge they learned in class. Interviewees also found students use higher-level thinking when projects have a sponsor or client. For example, Donna Taylor, the assistant director of professional development at WPI's STEM Education Center, had her students make a model of a molecular structure. Taylor made a scenario where a school for the blind needed models so students could learn about molecular structures. Not only did students have to think about making an atomic model, but how that model related to their "client". This included how the blind students could differentiate between different atoms. These types of projects also provided more motivation for students to spend time engaging with the class material. It also helped students work on their professional skills such as written and oral communications, including having more confidence and understanding when presenting their projects. However, our interviewees also identified some drawbacks.

The implementation of active learning will not necessarily work the first time an educator implements something new because there might be student resistance. The effectiveness is highly contextual since some students favor conventional teaching while others learn best with active learning. Sometimes, because of the ambiguity of active learning methods, students think that they are not actually learning. There was also an overall consensus among WPI faculty members that implementing these methods is very time-consuming and requires a lot of effort. The process of implementing active learning is cyclical and reinforcing. Once an instructor tries something new and they have a good experience, they are compelled to try to implement more active learning methods. Instructors also need to learn to step away and let students make their own mistakes, to be creative, and to deal with the frustration of not always knowing what the best solution is. This is one of the reasons why teachers should have a good support system that promotes the use of these methods from both colleagues and their institution. Institutional administrators have the responsibility to support faculty to use active learning methods, and then reward them when they do. If they do not reward the use of active learning then there will not be an adoption of these methods. We recognize that most of these factors are outside of our control, but acknowledge that they are important. After getting a better understanding of our interviewees' experience with active learning, we asked them about their familiarity with Bloom and SOLO taxonomies.

As we interviewed WPI faculty members, we gained insight on how they used learning taxonomies when planning lessons. It was interesting to see that all of them were familiar with Bloom's and used this taxonomy in their lesson planning, but they only heard of SOLO and none of them had used it. This indicates that SOLO might not be as popular with faculty members at WPI as we previously anticipated. We asked our interviewees how they used these learning taxonomies when creating lesson plans. Most of our interviewees had the same process of thinking about what they wanted their students to learn and what level of Bloom's they wanted their students to reach. Our interviewees also found it easy to classify their student learning objectives. There are many variations of Bloom's which helps with trying to brainstorm ideas for what activities to use at each level. There are also spectrums within each level of Bloom's hierarchy that map to age appropriateness, meaning that each verb has activities that correspond to students in pre-K to those at the university level. Knowing that faculty members find it helpful to use this taxonomy when creating lesson plans further supports our decision to use Bloom's in our classification structure. Lastly, we asked our interviewees what they believe the advantages and disadvantages of Bloom's taxonomy are.

Since Bloom's taxonomy is popular amongst most faculty members, it is easier for them to help one another with designing in-class activities and homework using Bloom's. This taxonomy also helps with specificity and intentionality by giving students rationale of why they learn certain topics. Interviewees expressed that students do not have to accomplish everything at the top-level of Bloom's taxonomy. In introductory courses, sometimes students need to learn concepts on the bottom levels such as *remember* and *understand*, on which they can build in future courses, which will eventually lead to the higher levels. Bloom's taxonomy compels instructors to think about what they want their students to learn and what Bloom's levels are most important. The knowledge we gained from our interviewees helped us become aware of important factors for our classification structure that we will discuss more in section 4.7.

We gained valuable insight from our interviews with WPI faculty members that helped us build our classification structure. From these insights, we became aware that it might be more difficult to pair active learning methods to student learning objectives for eleventh-year mathematics. Another important factor would be the teachers' experience levels with active learning. Since we are unaware of the experience that the teachers using STEMGen's pre-existing interface have with active learning, we should try to incorporate methods that any teacher can implement regardless of their familiarity with active learning. We also should try to recommend active learning methods that clearly show the learning outcomes asked of students.

By doing so, we make sure students realize that they are performing these activities with a goal in mind and can confidently identify it as real learning. After interviewing WPI faculty members regarding active learning and learning taxonomies, we asked similar questions to AUA faculty members.

4.2 AUA Faculty Interviews

We interviewed four AUA faculty members. We asked them about their thoughts and experiences regarding active learning. From these interviews, we learned about the benefits and drawbacks they saw with active learning methods. We also asked our interviewees about their experiences with Bloom's and SOLO taxonomies and any advantages or disadvantages they experienced. Based on these faculty members' experiences we also asked them to define active learning.

We began by asking the interviewees about their experiences teaching and to define active learning in their own words. Among the interviewees, the responses were similar to WPI faculty members, as they defined active learning as a broad concept that includes many methods. The interviewees expressed that implementing active learning was a difficult process at first due to inexperience, given the fact that these educators themselves were taught by the conventional methods. As mentioned by WPI faculty members, this implementation is an iterative process. This suggests that it will take Armenian instructors a few attempts to see beneficial returns for both educators and students. When we asked the interviewees about active learning methods that they successfully implemented into the classroom there were a few mentioned. One of the more common active learning methods was project-based learning. Interviewees had success with projects that took place within the classroom as well as projects where students worked with local businesses. Many of the professors also included short questions that they would ask throughout the lecture in order to get students thinking about the course material. After we learned how AUA faculty members implemented active learning we asked them about the positive and negative impacts of active learning.

When asked about the benefits, all of the interviewed faculty members said that in the course feedback the project-based courses received positive reviews from the students. The interviewees have observed that students engage more with the material and therefore they are more confident in it. AUA faculty members also felt that active learning, specifically implementing projects, gave them a better idea of student understanding throughout the course. This is because during the course of the project students would have weekly progress meetings with these professors. These meetings allowed the professors to see how the individual students engaged with the course material and each student's ability to apply the material to real life scenarios. While our interviewees listed some advantages, they also gave disadvantages.

Some of the drawbacks of active learning that interviewees experienced are the time it takes to create thorough lesson plans, the difficulty implementing these methods in large classes, and the necessity of keeping activities engaging for students. When talking about the issue of time needed to develop lesson plans a majority of interviewees said it was a problem that mostly affected the first few years that they started implementing active learning. Some interviewees said that once they develop a good lesson plan, they would reuse it for multiple years and it became easier to incorporate active learning over time. AUA professors are also constantly in search of new methods to use. When asked about how active learning may have improved or reduced student performance, most of the interviewees stated they would have to collect data regarding trends in grades to make a claim. Despite grades not necessarily improving with the implementation of active learning, these interviewees believe it has been generally beneficial to the students.

We asked our interviewees about their familiarity with Bloom's and SOLO taxonomies. The AUA professors we interviewed all said they use Bloom's taxonomy when creating lesson plans and none of them used the SOLO taxonomy. Given our research prior to the interviews we did not expect SOLO to have such little presence among our interviewees. Once we learned which interviewees were familiar with one or both of the taxonomies we moved on to ask them about the advantages and disadvantages of them. The AUA faculty members felt that using Bloom's was a benefit. The primary strength of Bloom's was that it allowed professors to easily determine the level of understanding they expect from students by the end of a lesson. Bloom's weaknesses include an over-reliance on the hierarchical structure by teachers. The effect from this over-reliance is class time lost when teachers focus heavily on including lessons that only cover lower levels of Bloom's taxonomy such as *remember* and *understand* before challenging students with the higher levels, *evaluate* and *create*. While progression is important, it can be beneficial for professors to give assignments or projects that challenge students to use a higher level of Bloom's than what they may have covered in class.

With the insights from both WPI and AUA faculty members, we were able to distinguish important factors for which we would need to account when building our classification structure in section 4.7. One of those factors was the implication that teachers will have to attempt active learning many times to be able to see the benefits. We will help teachers unfamiliar with active learning by suggesting methods they can use and perfect. Project-based learning was one of the primary forms of active learning used by a majority of faculty members from both WPI and the AUA. Since faculty members we interviewed from both institutions stated that project-based learning is effective in the implementation of active learning, we should try to add more methods involving that type of instruction in the classification structure. We should also aim to aid educators in creating thorough lesson plans by making the student learning objectives comprehensive for students with the use of learning taxonomies and suggest active learning methods to the instructors. Given our research prior to the interviews, we did not expect SOLO to have such little presence among our interviewees. This unfamiliarity with SOLO taxonomy among educators is something we needed to keep in mind when designing our classification structure. After we concluded our interviews with AUA faculty members, we went on to interview Armenian middle- and high-school teachers.

4.3 Armenian Teachers Interviews

After interviewing AUA faculty members we interviewed six Armenian middle- and high-school teachers. We asked them about their thoughts and experiences regarding active learning. From these interviews, we learned about the benefits and drawbacks they saw with active learning methods. Specifically, we analyzed the perceived benefits and drawbacks of how they implemented active learning into Armenian biology and mathematics classes at the middle- and high-school level. We asked our interviewees about their experiences with Bloom's and

SOLO taxonomies and any advantages or disadvantages they experienced. Based on these teachers' experiences we also asked them to define active learning in their own words.

When asked about active learning, our interviewees' responses were similar to each other, they defined active learning as a broad concept that includes various methods. These middle- and high-school teachers stressed how active learning involves relationships between peers and between students and their instructor. The interviewees expressed that implementing active learning was a difficult process at first because they, like the AUA and WPI faculty members, were taught by the conventional methods. When we asked the interviewees about active learning methods that they had successfully implemented into the classroom there were a few mentioned. Some of these methods included mind mapping and group work both inside and outside of the classroom. Mind mapping is when students are given a topic and work together to compile all the information they know about said topic. This is usually done when introducing new learning objectives. There were other unnamed methods that teachers used as well. One instance of this is a teacher who starts her classes by asking the students a question relating to the lesson of the day. After having students share their answers, she moves forward with the lesson without giving her students the correct answer. After implementing a few active learning methods such as group work, at the end of the lesson she once again reviews the question with students, who are now able to give more correct answers. The purpose of this is to have the students actively thinking and engaging with material throughout the lesson, opposed to only listening to a lecture. After we learned how the teachers implemented active learning, we asked them about the positive and negative impacts of active learning.

Similar to the subset of educators we interviewed previously from the AUA, Armenian teachers observed that a majority of students gave positive feedback regarding the use of active learning in class. One benefit that our interviewees noticed were higher levels of student engagement, and this increased engagement led to students being more confident in their understanding of the material. With group work, students have the chance to teach each other, which also improves knowledge and self-efficacy. One middle-school teacher said that even students who were initially against the various activities were influenced by how much their classmates enjoyed them and became more active participants.

Aside from the variety of advantages the Armenian teachers observed, there were a number of disadvantages that came with the implementation of active learning. They were similar to those faced by AUA faculty members. These drawbacks were the time taken to create thorough lesson plans, the difficulty implementing methods in large classes, and the challenge of keeping activities engaging. A majority of interviewees said that the issue of time needed to develop lesson plans was a problem that mostly affected their first few years they started implementing active learning. A majority of the middle- and high-school teachers we interviewed expressed the challenge they found when trying to implement active learning methods in larger class sizes. They said they are hesitant to use active learning methods such as in-class group work in larger classes of 30 students because students easily lose focus and teachers often encounter behavioral issues, which makes it difficult for the teacher to instruct the entire class. These interviewees said that class sizes of approximately 15 students are best for implementing active learning due to the ability to focus more on the individual students and monitor the classroom. In smaller classes, students are able to focus on their assigned groups and to better assist each other. When asked about how active learning may have improved or reduced student performance, the Armenian teachers, like the AUA faculty members mostly said they would need to collect data regarding trends in grades to make a claim. Although our interviewees did not gather data and examine if active learning affected their students' grades, they believe it has been generally beneficial to the students.

After learning about how Armenian teachers implement active learning as well as the pros and cons of the various methods they use, we asked the interviewees about their familiarity with Bloom's and SOLO taxonomies. Middle- and high-school teachers we interviewed were overall less familiar with Blooms and SOLO than the AUA faculty members. While all of the interviewed middle- and high-school teachers recognized Bloom's from workshops and training, many of them have not used the taxonomy in relation to their own lessons. None of the interviewed teachers had ever used SOLO when creating lesson plans or planning learning objectives. Once we learned which interviewees were familiar with one or both of the taxonomies, we moved on to ask those specific interviewees of the advantages and disadvantages of the taxonomies.

After understanding where our interviewees stood in regards to familiarity with Bloom's and SOLO taxonomy, we asked them the perceived benefits and drawbacks when using it in the classroom. The teachers who used Bloom's felt it was very beneficial for very similar reasons to the AUA faculty members. The primary strength of Bloom's was that it allowed professors to easily determine the level of understanding they expect from students for each lesson. Armenian teachers who had experience using Bloom's in classrooms had less to say about any potential weakness than the other groups of interviewed educators. While the Armenian teachers familiar with Bloom's taxonomy recognized that there are weaknesses, they could not name any of them.

After finishing all our interviews with all three groups of educators, we had gained a good understanding of the implementation of active learning and Bloom's and SOLO taxonomies that helped us in creating our classification structure. One of the aspects we needed to consider was class size. A lot of the Armenian teachers discussed that larger classes were a deterrent to implementing active learning. This is important to note because we can look for active learning methods that can work for larger class sizes. We aim to encourage teachers to use more active learning by doing so. Based on the feedback from all three groups of educators (WPI faculty members, AUA faculty members, and Armenian middle- and high-school teachers) and how none of the three use SOLO taxonomy. We needed to consider the best way to implement SOLO into the classification structure or if we should at all. After concluding our interviews with Armenian teachers we proceeded to interview Armenian alumni, current college students who had attended middle- and high-school in Armenia, regarding their experiences with the school system.

4.4 Armenian School Alumni Interviews

To understand more about student perspectives regarding the Armenian education system, we interviewed Armenian school alumni. In our interviews, we asked these alumni how their schools structured classes, how interested they were in STEM subjects, and their experiences with active learning. Most importantly, we asked our interviewees if they had any recommendations regarding how educators can better teach their classes and what would help improve the education system in Armenia. In order to better understand what type of schools our interviewees attended, we started off by analyzing our interviewees' demographics and how their class schedules were structured.

We interviewed two alumni who attended a variety of schools in Yerevan, Armenia ranging from primary school (Khachik Dashtent No. 114 and Anania Shirakatsy Lyceum), to middle- and high-school (Quantum College and Mkhitar Sebastatsi Educomplex). When first introduced to STEM courses in the fourth-year, Armenian students mainly learn about general sciences, but from their fifth-year to ninth-year, physics, chemistry, and biology tend to become the primary focus. Alongside taking these science courses, the students have the opportunity to take computer science courses in either their eighth- or ninth-year. These computer science classes teach basic skills such as binary number conversions and Excel. In their tenth-year, students have the option to focus on one of these paths: math and physics, biology and chemistry, or a general path that consists of humanities classes such as languages, history, or geography as well as business/economic classes. When entering their eleventh-year, students end up taking review classes such as algebra, geometry, and calculus in order to prepare for their high-school exit exam (which is the same as their college entrance exam). These college entrance exams are similar to the SATs that American students take. Aside from these STEM subjects, students take history, Armenian, Russian, and English classes. From our interviews, our interviewees learned STEM subjects inside the classroom, but their interest in STEM piqued outside the classroom through their experiences of outside programs and clubs.

As these alumni learned a variety of STEM subjects throughout their time in school, they had the opportunity to enhance their STEM learning with the use of clubs and programs. Their schools offered clubs as extracurricular activities. Our interviewees also attended programs outside of school. These clubs and programs piqued their overall interest towards STEM subjects. The alumni that we interviewed stated that many Armenian schools have STEM-based clubs such as those that focus on math, science, physics, and aside from STEM, English. These types of clubs attend competitions twice a year where students are given three to four questions that they have to finish within three and a half hours. These competitions would start at the school, then turn to a district-wide competition, then there would be a national competition. These types of clubs gave students an opportunity to focus more on STEM subjects and specifically the subjects that students liked the most. Alongside these clubs, there are also after school programs that students attend where they learn subjects such as music, technology, art, computer science, data science, and more.

TUMO is a program that offers students an opportunity to learn more and stay engaged in STEM-related subjects. This program increased one of our interviewees' interest in STEM subjects because it was mainly online lessons and they learned at their own pace. At the TUMO center, each student is at a computer taking lessons at their own pace and a teacher walks around in case anyone needs help. The use of computers and technology in a learning environment confirms the information found in the background chapter that the use of technology such as graphics and videos helps engage students in the classroom. With the technological resources available in TUMO, one of our interviewees thoroughly enjoyed their time in that program. Our interviewees' overall interest in STEM piqued due to the implementation of STEM-related clubs and programs rather than in the classroom due to the lack of active learning that they experienced.

Throughout our interviews, we asked our interviewees to recall their experiences with active learning throughout their education. Unexpectedly, our interviewees stated that the techniques used were mainly memorization and independent work and that there was little use of active learning or collaboration with others. Our interviewees stated that a normal day for their mathematics class was the teacher lecturing, then giving students 30 problems to solve for homework in order to strengthen their problem-solving skills. For a normal biology class, the teacher assigned a chapter to read and homework problems for the next day. During the next class time, the teacher would randomly pick three to four students to individually present on what they read and do problems on the board. Our interviewees did not like this type of technique because it led to maladaptive mechanisms that they used in the classroom. A maladaptive mechanism when it comes to active learning, as stated in the background chapter, refers to the action of students avoiding eye contact with the teacher, not raising their hand, and answering questions quickly (Brigati, England, & Schussler, 2020). For example, because one of our interviewees did not like this technique, they would try to avoid getting called on by their teacher. Additionally, the lack of active learning implemented lowered their confidence in the classroom. After asking our interviewees whether or not they experienced more of an active learning type of teaching style or conventional type, they stated that they experienced more conventional teaching styles. The reason for this is because there was little collaboration with others and there were rarely any team projects. Our interviewees stated that high-school mainly contained conventional teaching styles and that teachers only used exams to test students' knowledge rather than projects and presentations. When experiencing a lack of project-based and active learning methods such as think-pair-share and peer communication, one of our interviewees felt that it took time to adjust to the shift to active learning in college. After analyzing our interviewees' answers, active learning not only helps students better understand the material, but it also prepares a student for college and their professional career. Active learning can better prepare a student for college because if our interviewees did go through an active learning system, they would have better adjusted to college when it comes to working on projects with others and collaboration. One of our interviewees stated that when going to college, the project-based learning system was not hard but it definitely took time to adjust. As seen that active learning was not a main factor of the education system, we asked our interviewees to recommend ways to improve the system.

One recommendation discussed by our interviewees was more project-based learning and group work. Additionally, the implementation of cross-classes is a recommendation that one of our interviewees suggested. Cross-classes are when there are not the same students in every class period together; instead, there is a different mix of students. For example, a biology class can contain 20 students, but when students attend a different class such as math, it will contain a different set of 20 students. It is very interesting to see that in America, the majority of middle- and high-schools implement cross-classes, yet in Armenia they do not, resulting in a large difference between the two education systems. Rather than having the same people for every single class, having different classmates within different classes would be beneficial because there would be different mindsets that would allow for more opportunities to help others and create more friendships. Although cross-classes are a great recommendation, there can also be a limitation that may not allow for cross-classes, such as class sizes. Our interviewees graduated in a class of about 25 students and it is very difficult to provide different classmates for different subjects if there are not enough students in general. Lastly, regarding class sizes in public schools, some public schools contain 40+ students per class. This is a weakness in the education system because this creates a problem where students that end up sitting in the back of the classroom cannot hear the teacher therefore are not engaged in the material. Due to this problem, cutting down class sizes is another recommendation. Both teachers and alumni mentioned implementing smaller class sizes will benefit both groups. Smaller class sizes allow for more opportunities for teachers and students to have more one-on-one discussions with each other that will keep the students engaged in the material.

Similar to the interviews we had with educators, the interviews with Armenian alumni helped us obtain helpful information that will help in forming our classification structure. Based on the enjoyment and involvement one of our interviewees had with TUMO, the use of graphics, videos, and diagrams in some of our pairings could help engage students in class. In addition, our interviewees recommended adding more collaborative work; we aim to do that with the active learning methods we suggest in our classification structure. After interviewing Armenian alumni, we distributed surveys to see the current perspectives of Armenian students regarding the education system.

4.5 Surveys

After interviewing Armenian alumni, we administered surveys to current Armenian students to understand their perspectives on their STEM education system. Most questions were multiple-choice or a Likert scale from one to five (one being the least and five being the most) with a few short answers. We used these questions to gauge students' interest in STEM subjects, how students became interested in STEM, and any patterns regarding why. We also focused on the current students' satisfaction with STEM courses, as well as suggestions for activities to include in STEM classes. We analyzed students' interest in pursuing STEM in college as well as their reasons why, and compared those reasons to the students' level of satisfaction in taking STEM courses. We started the survey by asking students for their year level and their current satisfaction with the way they learn STEM concepts.

Over 100 students responded to our survey, which allowed us to get a good sample size to analyze their satisfaction with how they learn STEM. In terms of demographics, the majority of responses were from tenth-year students (36 responses), then there was the same number of eighth- and ninth-year students (28 responses each), followed by seventh-year students (21 responses). Unfortunately, there were only a few eleventh-year students (4 responses), and there were no twelfth-year students that answered our surveys. Overall, this gives a good diversity of middle- and high-school students, but it would be more diverse if there were more responses from seventh- and twelfth-year students. The majority of students were either neutral, satisfied, or very satisfied with how their teachers are teaching STEM concepts (Fig. 4). Over 50% of students were satisfied, around 20% of students were neutral, and around 20% of students were very satisfied with the way their teachers teach STEM subjects. Less than 5% of students felt dissatisfied or very dissatisfied. This shows that overall students are satisfied with the way they are taught STEM concepts. It was also interesting to see that other than eleventh-year students, there was at least one person in each level that was dissatisfied with the way they learn STEM concepts. This indicates that there is not one particular grade level in which students start to become dissatisfied with the way they learn STEM. After we asked students' current satisfaction with the way they learn STEM, we inquired when they started to become interested in STEM.

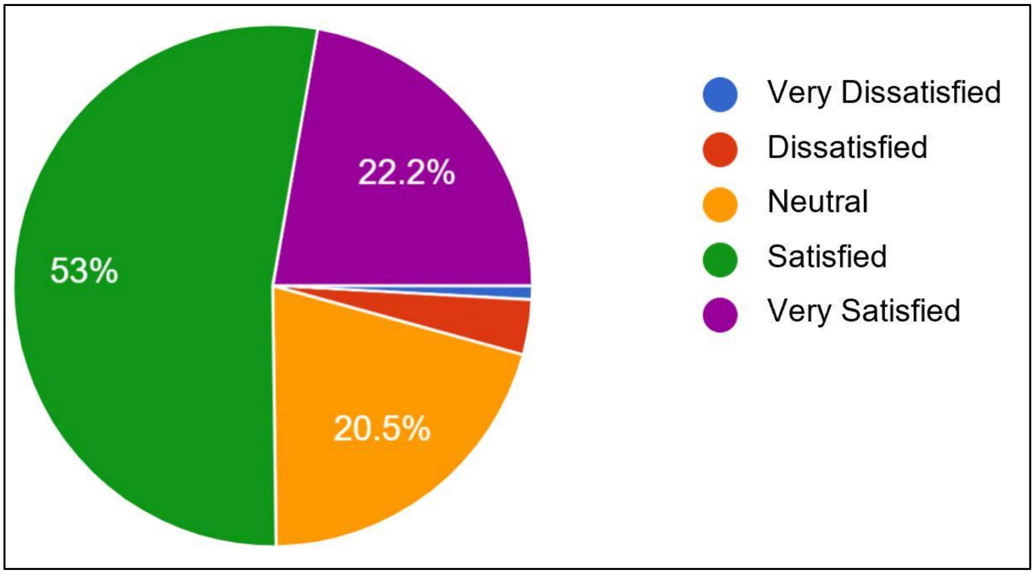

Figure 4: Armenian students' satisfactions with how their taught STEM subjects

We asked students what year they became interested in STEM and what made them become interested. Almost 35% of our participants said they became interested in STEM in the seventh-year and the second most common response was sixth-year. Other responses stated they became interested in STEM as young as first-year up to eleventh-year. A few students said they were always interested in STEM while others said they are not interested. We asked in the following survey question why students became interested in STEM. We observed that students gained an interest in STEM in the seventh-year because that is when they first started studying STEM subjects such as mathematics, biology, physics, and chemistry. A lot of participants were particularly interested in mathematics. In addition, another common response from students was they want to become a doctor. Some of the responses that explain why students lost interest in STEM were that the subjects became more difficult and that the way they were taught the material was less interesting. After knowing what year and why students started to become interested in STEM, we also wanted to know what particular subjects they were interested in.

To understand particular subjects of interest, we used a Likert scale for students to rate a variety of STEM subjects. If students responded with a five (which indicates that they learned the most from that subject), we asked them to explain why. On average, when given the choice between physics, biology, chemistry, computer science, algebra, and geometry, all the students ranked algebra as the subject they are most interested in, followed by biology, physics, geometry, computer science, and chemistry (Fig. 5). When averaging all the ratings students gave each subject, every subject ranked at least a three or higher and did not exceed four. This indicates on average students' interest in STEM subjects is neutral towards those subjects and there is not a specific preference of one particular subject over another. Similar results were found in examining students' responses based on grade level, indicating that students' interest in STEM subjects is not year-specific. When asked what subjects they best perform in given the subjects biology, physics, chemistry, mathematics, and informatics, on average students responded that they performed best in mathematics closely followed by informatics, biology, physics, and chemistry (Fig. 6). When analyzing the averages from individual year levels, ninth- and tenth-year students followed this specific trend, but seventh- and eighth-year students ranked physics and biology as the highest. This shows that the middle-school curriculum might focus on biology and physics while high-school puts a greater emphasis on mathematics. When asked why they rated any subject(s) as a five, the majority of the responses stated that it was because those particular subjects were interesting and that they will later need to know about those subjects in their profession. This indicates that students are more motivated to study well in the subjects in which they are interested in. Since these students are cognizant that these concepts can help them in the future, this shows that students are interested in pursuing a higher education and career in STEM which is shown from our survey trends.

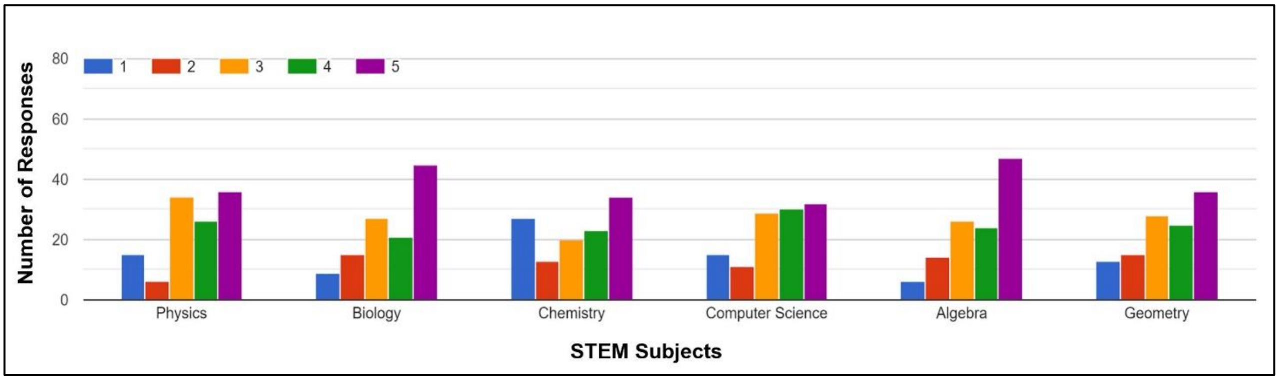

Figure 5: Armenian students' interests in STEM subjects

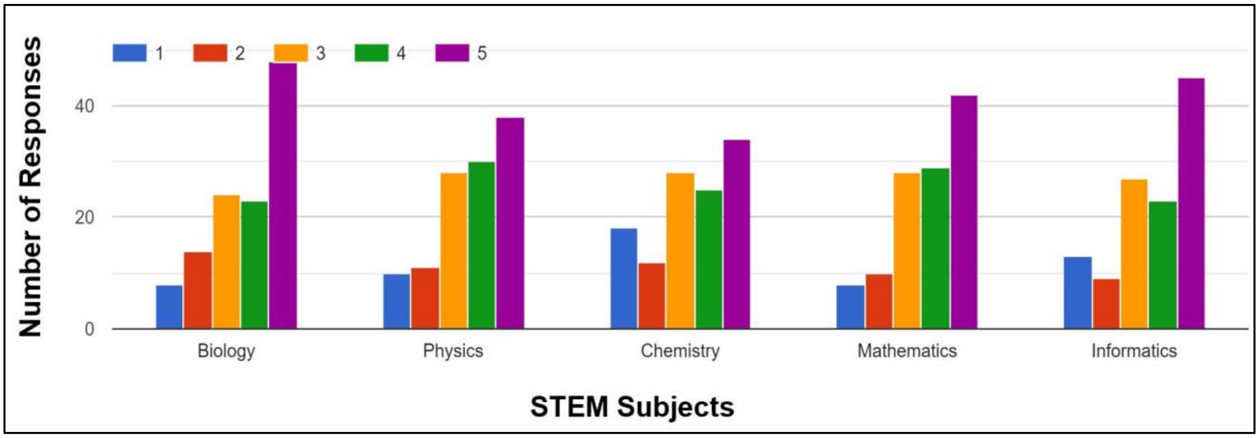

Figure 6: Armenian students' performances in STEM subjects

We also asked current Armenian students if they wanted to pursue a higher degree in STEM education and whether or not they then planned to have a profession in those fields. Students' interests in achieving a higher degree in STEM education was around a 3.6 (Fig. 7). Seventh-year students' interest in pursuing a higher education in STEM was at a 4.3. It was interesting to see eighth- and ninth-year students' interest in pursuing a high degree in STEM was 3.2 and 2.96, respectively. However, tenth- and eleventh-year students ranked it on average four or higher. These answers correlated to our next question when we asked students if they planned on pursuing a career in STEM (Fig. 8). A majority of the tenth-year students said they either planned on it or they were unsure. The majority of ninth-year students said they did not plan on pursuing a career in STEM while most eighth-year students said they were unsure. Overall, there was a fairly equal distribution between all students on whether they wanted to pursue a career in the STEM field with a slight inclination towards yes and they are not sure. When we asked students to elaborate on why they do or do not want to pursue an occupation in STEM, students who wanted to said that they really like these subjects. Common professions students listed they wanted to be were doctor and computer programmer. Students who said they do not want to pursue a career in STEM said they were primarily interested in the humanities or that they had chosen a different field to pursue. A common profession listed was a lawyer, or that they wanted to study foreign languages. Some students responded saying that although they do like STEM subjects, they don't want to go into STEM-related careers.

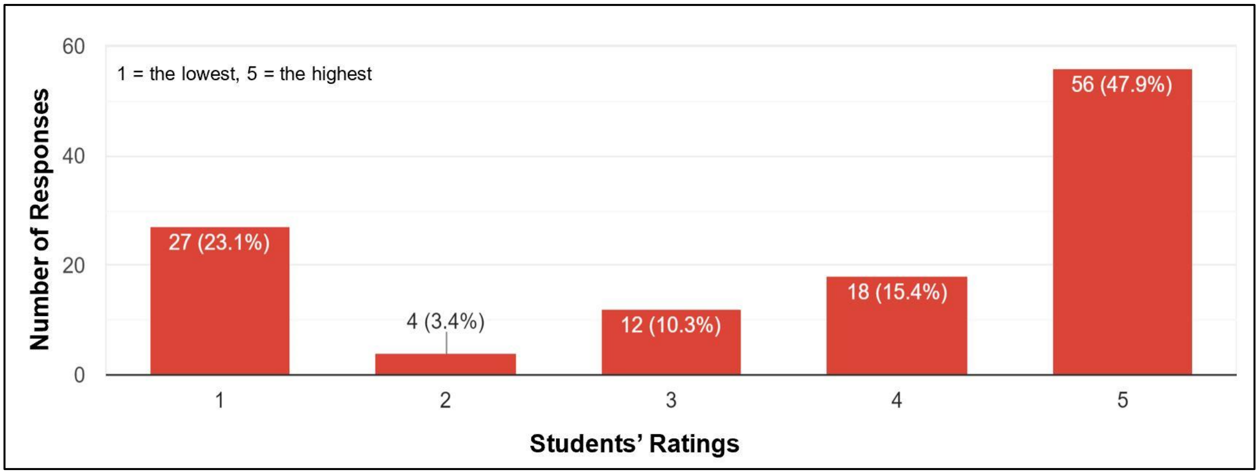

Figure 7: Armenian students' interests in pursuing a higher degree in STEM education

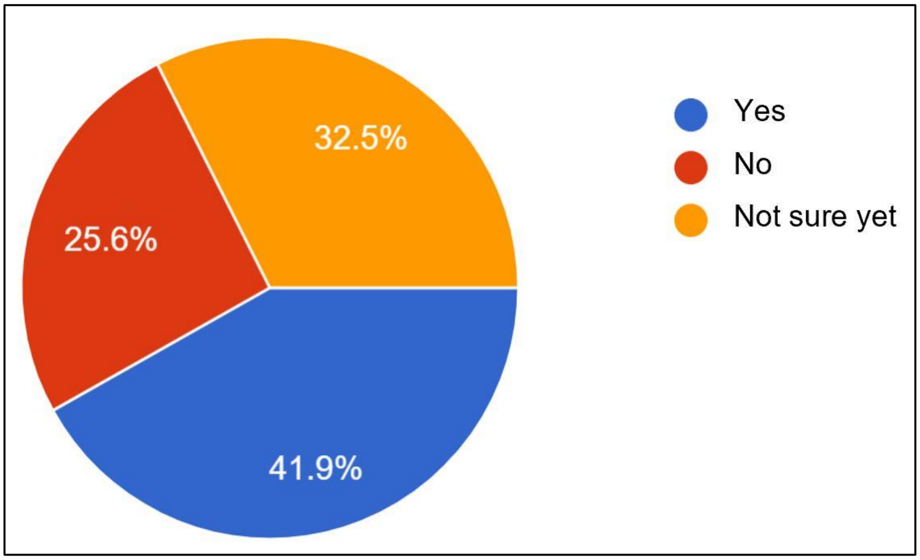

Figure 8: Students' responses on whether they believe they will have a career in STEM

After understanding their current perspectives on their future plans in STEM, we asked students if they had any suggestions to improve the way they learn STEM subjects. A lot of students requested practical experiences and lab experiments. One student even requested being taught how these concepts and subjects relate to certain professions. Around 20 students suggested for teachers to teach in a more interesting and interactive way along with using more modern methods of teaching. Students also asked for visual experiences such as watching videos and if subjects could be taught more clearly. A lot of students also answered that they could not come up with anything or they were satisfied with how they learned STEM material. To confirm that having a more hands-on experience in the classroom will interest students more, one student responded that the reason they are satisfied in the way they learn STEM was all of the laboratory work they are able to do.

The answers we received for the last question in particular confirmed that our classification structure will help improve teaching in STEM. When we asked them if they had any suggestions to improve the way they learn STEM subjects, a lot of responses suggested more interactive methods. Our classification structure will do this by suggesting active learning methods that will help students interact more with each other and the material they learn. In addition, students asked for more modern methods that we used in our classification structure, using the sources our sponsors and one of our interviewees provided us. Students also asked for practical experience that we can achieve through our classification structure by adding more methods that involve having a sponsor or client that can relate to the activity. This way, students can connect with the material and really use their problem-solving skills to not only apply the material they learned, but how they can use it in real applications. In addition, with the use of Bloom's taxonomy, we aim to help students understand why they are learning this material through the use of clear and distinct objectives. The utilization of the literature our sponsors and our interviews provided us aids our ability to accomplish this classification structure and suggests active learning methods.

4.6 Literature Review

We obtained American lesson plans to gather topics and objectives for eighth-year biology and eleventh-year mathematics. We used these resources because they were common standards that would get us a better idea of potential STEM concepts Armenian students learn in school. The source we found for biology was the *Next Generation Science Standards* and the *Massachusetts Mathematics Curriculum Framework-2017* for mathematics.

We used both of the American biology and mathematics standards to obtain the topics and objectives for our classification structure. The *Next Generation Science Standards* provided us with five topics for biology and the *Massachusetts Mathematics Curriculum Framework - 2017* had six topics for mathematics. Under each topic from both sources were a number objectives that are expected of students to know. We used these objectives as guidance to use for our classification structure. We mapped each objective's verbs to map to one or more Bloom's levels. We decided to use these sources because the topics and objectives should be similar to what current Armenian students learn in eight-year biology and eleventh-year mathematics. Our sponsors advised us to use the *Next Generation Science Standards* because STEMGen referenced this source when making the Armenian rubrics for subjects. We used the *Massachusetts Mathematics Curriculum Framework - 2017* since it was a standardized framework that would be similar enough to mathematical concepts taught in Armenia. After obtaining these resources, we were able to suggest active learning methods corresponding to the learning objectives in our classification structure.

4.7 Classification Structure

We built our classification structure focusing on eighth-year biology and eleventh-year mathematics to better equip teachers with active learning methods using Bloom's taxonomy. Since we were unable to get the Armenian rubrics in time, we used the *Next Generation Science Standards* and the *Massachusetts Mathematics Curriculum Framework - 2017* to obtain topics and objectives for biology and mathematics respectively (Next Generation Science Standards, 2013; Massachusetts Department of Elementary and Secondary Education, 2017). Using these sources, we had five topics to cover for biology and six for mathematics. Within those topics we included SLOs that we used to suggest active learning methods. We formatted our classification structure by having one Excel workbook for each subject. Each sheet in the workbook was one topic, and each sheet contains tables, one for each objective. Each objective used specific verbs that we were able to map to one or various Bloom's levels. We decided on only using Bloom's to categorize student learning objectives since SOLO taxonomy was not well known with any of our interviewees, and most of the Armenian middle- and high-school teachers were only familiar with Bloom's. We looked at each objective and the verb used in that objective. We identified what the teacher would like their students to accomplish and what knowledge they wish their students to gain with this objective. Based on this evaluation, we were able to best categorize each objective into one or more Bloom's levels, from there we were able to look at the *25 Ways for Teaching Without Talking* and *226 Active Learning Techniques* to best pair active learning methods to each level (Geoff Petty Sutton Coldfield College, 2002; Iowa State University Center for Excellence in Learning and Teaching, 2017). We included an example of a table when we used every Bloom level for one objective (Fig. 9), and we also show a version with only two Bloom levels (Fig. 10). We only mapped to two Bloom's levels because mathematics is such a hard topic in which to implement active learning methods and there is such a limited number of engaging activities when it comes to solving algebraic equations. We chose the level, *understand* to help students interpret the concepts and the relationship between equations and geometric properties. We chose *create* to help students visually represent on a graph coordinates and how they can take the shapes of geometric shapes which is the overall goal. We took into consideration what our participants noted in our interviews and in the surveys. We tried to make the learning objectives very clear with what level they fell under and tried to find active learning methods that would engage students in the classroom in various ways whether it was through group collaboration or adding more activities that involve students making something they could visualize. We aim to help teachers by suggesting active learning methods in the classroom and help students by providing clear student learning objectives using Bloom's taxonomy. For eighth-year biology, we created one Excel workbook with five spreadsheets corresponding with the five topics from our literature review and with a total of 24 tables. For eleventh-year mathematics, we created one Excel workbook with six spreadsheets and a total of 15 tables.

Objective: Have students learn about DNA and RNA and know the differences between them			
REMEMBER	**Teaching by Asking -** Teachers will give more of a Q&A but will be very specific to DNA/RNA concepts and those questions can be put on exams	**Snowball -** Similar to "Teaching by Asking" but rather than discussions, students will have to write it down and then will discuss with the person next to them their answers	**Cooperative Learning -** Similar to "Teaching by Asking" but this time students are given resources and they have to use the textbook and specific information
UNDERSTAND	**Headings -** Students are given basic concepts of DNA and RNA and then would have to summarize the information into a heading	**Key Points -** Before teaching the students the concepts, split the students into 2 groups (DNA/RNA), have them read a section of text and as a group, come up with 5 main key points they took away	**Peer Teaching -** Have a students in pairs and then one student teaches their partner DNA and the other teaches RNA and then switch
APPLY	**How Does it Work? -** Before presenting the topic, show the students a diagram or example of DNA/RNA and ask them what/how do they think it works	**Explaining Exemplars -** Give the students examples of good practices of the topic/correct ways it is used and then bad examples of the topic and have them identify what is correct or not	**Flowcharts/Diagrams/Drawings -** Have students draw a diagram of DNA/RNA and then in the diagram explain how it is used in real life organisms
ANALYZE	**Student Presentations -** Students should be given a topic of their choice (either DNA/RNA) and present the functionality	**Decisions-Decisions -** Students will create 5-10 "Summary Crads" to summarize the key points that they took away from class	**Spectacles -** Students are given a "matrix/table and the rows are DNA/RNA and the columns are questions and they have to answer for each. Can be done as a class or groups.
EVALUATE	**Class Brainstorm -** Teacher asks questions regading the functionality of each strand and each student takes turns explaining what they know	**Peer Explaining -** Students pair up for 5 miniutes, they each read the textbook about DNA/RNA (or one student reads about DNA and the another about RNA) and then they explain it to each other	**Snowballing Questions -** Students are given an assignment with questions and in groups of four, they discuss
CREATE	**Flowcharts/Diagrams/Drawings -** Students can be assigned in pairs to draw the differences that they learned in lecture	**Compare and Contrast Discussons -** Students are able to dicuss in groups the aspects that are similar in the DNA and RNA structure and what is different	**Jigsaw -** you can split the class into 2 groups. One focuses on DNA and the other focuses on RNA and then they should teah each other the differences

Figure 9: Classification structure showing a biology objective mapped to all the Bloom's levels

Objective: Use coordinates to prove simple geometric theorems algebraically			
UNDERSTAND	**Jigsaw -** Students are split into groups, algebraic geometric theorems, line segments, polygon, and areas of triangles and rectangles, etc. and those groups will focus on specific topic then will teach students in the other group their respected topic	**Peer Explaining -** Students will be in pairs and one students will have a topic for example, theorems and equations and the other student will have another topic such as geometric shapes and then they have to teach each other their topics then wirk together to see how they can be related	**How does it work? -** The instructor first gives students a text they havent read regarding coordinates and their relationships to geometric shapes and then they have to share their main key take aways
CREATE	**Diagrams -** On a diagram, students can visually represent coordinates on a graph and on that diagram, they can also represent formulas, parallel, perpendicular lines, line segments, and perimeters of polygons	**Transformation -** Students are given information regarding coordinates and geomtric theorems and either in groups, they have to present the information in another format such as a video or report	**Student Presentation -** In pairs, students should present their understanding on how to prove or disprove how coordinates on a plane can represent figures

Figure 10: Classification structure showing a mathematics objective mapped to two Bloom's levels

5. Recommendations

With our classification structure, we recommend various ways that STEMGen can incorporate it into the pre-existing interface that will be more user friendly for teachers. After learning about the Armenian STEM education system and creating our classification structure, we have recommendations that will further help Armenian teachers implement active learning methods that will increase student engagement in the classroom. Alongside our recommendations on how the classification structure can be more useful for the future, we also recommended alternative research techniques that will help improve the pre-existing interface and what researchers should be aware of when continuing this project.

5.1 Armenian Educators

We received great insight from the faculty members at the AUA and Armenian educators from public schools, but when continuing this project in the future, we recommend additional researching be carried out. When interviewing Armenian teachers from public schools that are a part of the STEMGen program, we recommend interviewing a broader range of teachers that teach different STEM subjects rather than just interviewing biology and mathematics teachers. Since STEM encompasses a wide variety of courses (such as chemistry, physics, calculus, trigonometry, etc.), receiving input from educators that teach different subjects and different years would be valuable. This would help our sponsors get a better understanding of how a larger number of educators feel regarding active learning. Furthermore, we recommend that educators of the same subject should share lesson plans and rubrics to foster collaboration among colleagues. Collaboration will help teachers grow as educators whether it's through sharing lesson plans through email or talking to one another. In addition to interviewing public school teachers, we recommend interviewing principals of middle- and high-schools as well. Interviewing the middle- and high-school principals will help researchers get a better understanding of the overall structure of how Armenian middle- and high-schools work and know what administrators think can improve. Lastly, we recommend a mentorship between AUA faculty members and Armenian public school educators. For example, during a part of the STEMGen program's teacher workshop, an AUA professor could pair with a middle- or high-school teacher. Many professors implement active learning methods in college courses and they would be able to help public school teachers implement the same methods. Not only will this help the teachers grow as educators, it can help students be prepared for college. Alongside interviews with Armenian educators, when gaining the perspectives of Armenian school alumni, we were able to think of recommendations that STEMGen can implement.

5.2 Armenian School Alumni

When interviewing Armenian school alumni, we wanted to understand the students' perspectives on the Armenian STEM education system. Unfortunately, we only interviewed two. For further research, we recommend interviewing a more diverse group of Armenian alumni. For example, we recommend interviewing more alumni that went to public school. When interviewing Armenian school alumni, only one of our interviewees went to a public primary school, and then a private school for middle- and high-school, but the majority of the schools that we discussed were private schools. Based on our interviews, we suggest the implementation of more collaborative work in middle- and high-school classrooms. Lastly, we recommend that our sponsors at the STEMGen program collaborate with other STEM programs in Yerevan. After an interview with one of the alumni, we found out that TUMO is another program that helps students to engage in STEM subjects. We recommend that there be a collaborative discussion in the future with TUMO and the STEMGen program. Since TUMO was founded in 2011, it has more experience with student engagement, and STEMGen's summer programs can collaborate with TUMO to help students gain more knowledge regarding STEM subjects. In all, when working to help the STEM education system, alumni's perspectives are very valuable alongside the perspectives of current students.

5.3 Surveys

In order to obtain insight from current students, the use of surveys and gaining their perspectives can improve. As the distribution of surveys was a helpful way to connect with current students to understand their perspectives on STEM education in Armenia, we recommend that there be changes to our survey along with additional surveys. One change we recommend for the surveys we used is more open-ended questions. If there is no need for a translation into English, there should be more questions and more open-ended responses on the surveys. This will allow students the ability to answer questions more in depth with details so that researchers can identify strengths and weaknesses in the education system. In addition to more open-ended questions, we also recommend distributing the surveys to more grade levels. We were only able to distribute our survey to middle- and high-school students. Future researchers can adjust the questions and create various surveys in respect to year level to allow them to gain middle-school students' perspectives on the STEM education system. In addition, we recommend spending more time collecting student responses. Researchers might be able to collect responses from more year levels. For example, when we allowed for two weeks, we did not receive any responses from twelfth-year students but if there was more time, it might have been possible. Finally, we recommend asking students in the surveys to be specific when suggesting any improvements that can be done in the education system. With this information, researchers can narrow down some areas of weaknesses. When working on retrieving helpful information regarding students' perspectives through the use of surveys, we recommend helpful techniques when retrieving lesson plans and rubrics from Armenian teachers.

5.4 Literature Review

We were unsuccessful in obtaining Armenian lesson plans and rubrics because our sponsors had to go through the Armenian Ministry of Education and, due to our seven-week timeline, we were not able to get them in time. We recommend that when trying to get lesson plans and rubrics, to try to put in a request as quickly as possible. Alternatively, we researched American rubrics that relate to the topics taught in Armenian schools. We used the United States *Next Generation Science Standards* and the *Massachusetts Mathematics Curriculum Framework - 2017*. The only updated mathematics framework was from 2017 so for the future, we recommend using a newer version of the framework. We also recommend comparing those lesson plans and rubrics to American counterparts when possible to see if there are any similarities between the two standards of education. For future work, we lastly recommend looking for a variety of rubrics in the United States. For example, we only used rubrics and objectives from the Massachusetts curriculum, but looking for a broader range such as different states (ex. New York, California, Virginia, etc.) will be beneficial to get an overall understanding on what should be the standard learning objectives for STEM subjects.

5.5 Classification Structure

We identified multiple aspects of this classification structure that STEMGen can incorporate when implementing this structure into the pre-existing interface that teachers will use. One of these recommendations is including examples on how to implement the suggested active learning method. For example, if a teacher clicks on the method “Cooperative Learning,” that is seen in Fig. 9, the teacher should be given a list of worksheets and lesson plans that work with that specific active learning method. Other suggestions include seeing previous works done by students, the exact rubrics or assessment tools that teachers have used to evaluate their lesson’s effectiveness, and possible links to videos that teachers can show to better engage their students at the start of class and also introduce them to topics that they are going to cover. Furthermore, previous teachers that implemented a particular active learning method should have the ability to leave summarized notes/advice that will help with the implementation of the specific learning method. With our classification structure we used the methods from the *25 Ways for Teaching Without Talking* article given to us by our sponsors. We recommend that in addition to those 25 active learning methods, our sponsors should implement more active learning such as those listed in the *226 Active Learning Techniques* article given to us by one of our interviewees. With the addition of more methods, teachers will have a broader range of techniques that they can implement if they did not like any of the original 25 methods. We further suggest that rather than just containing subjects such as biology and mathematics and strictly eighth- and eleventh-year, there should be all subjects covered at levels sixth- through twelfth-years. Lastly, we recommend that when incorporating the classification structure into the interface, STEMGen translate it completely into Armenian. With these recommendations, we hope that our classification structure and the interface that the teachers will use positively impact their teaching in the classroom.

6. Conclusion

The Armenian government recognizes the economic and social benefits of well-developed STEM industries, but currently there is a lack of STEM-educated workers. After examining the leading causes of this, officials are looking to address the primary issue, which is the current STEM education system. In order to improve the country's STEM education system, the AUA implemented programs to increase student engagement in STEM-related subjects that will lead them to pursue STEM careers. STEMGen focuses on empowering teachers to use new teaching methods which will better engage their students as well as help them develop the skills needed to properly implement these methods. The purpose of our classification structure is to assist in the development of Armenian teachers' ability to use active learning methods and learning taxonomies.

With our classification structure we aim to guide teachers who have little experience with active learning in implementing it more in the classroom. A major part of this guidance includes how to effectively use Bloom's taxonomy. Through the use of this taxonomy, students will have clearer learning objectives and outcomes, providing them with a better idea of why they are learning this material and what is expected of them. The suggested active learning methods will help students gain skills such as communications skills and self-efficacy. Active learning will also help students engage more with class material. This engagement will allow students to have a deeper understanding of the content and make connections based on their own experiences. Once students have experience with learning through the use of active learning methods, they will be able to apply skills they develop when taking other classes and later on in life. One of the skills active learning pushes students to use is critical thinking, a skill that will improve problem solving abilities. This makes it an applicable skill later in life when students encounter difficult tasks either at work or within their personal lives. Aside from the benefits to the individual student, the country as a whole will benefit from STEM education.

Ideally the improvements in STEM education, with the help of the implementation of our classification structure, will lead students to take a greater interest in STEM subjects and lead them to pursue degrees in the various related fields. An increase in STEM professionals will allow the country to be more competitive on a global scale. STEM industries help in developing innovations which will increase economic growth and quality of life for citizens. Specific industries such as manufacturing and transportation will benefit from the increase in STEM-educated workers, as these industries directly impact the infrastructure of a country and their improvement will positively impact Armenia's global standing.

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