Using Biomedical Engineering and "Hidden Capital" to Provide Educational Outreach to Disadvantaged Populations

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***Abstract*— A hands-on learning module called "Science of the Slam" is created that taps into the passions and interests of an under-represented group in the fields of Science, Technology, Engineering and Mathematics (STEM). This is achieved by examining the use of the scientific method to quantify the biomechanics of basketball players who are good at performing the slam dunk. Students already have an intrinsic understanding of the biomechanics of basketball however this "hidden capital" has never translated into the underlying STEM concepts. The effectiveness of the program is rooted in the exploitation of "hidden capital" within the field of athletics to inform and enhance athletic performance. This translation of STEM concepts to athletic performance provides a context and a motivation for students to study the STEM fields who are traditionally disengaged from the classic engineering outreach programs. "Science of the Slam" has the potential to serve as a framework for other researchers to engage under-represented groups in novel ways by tapping into shared interests between the researcher and disadvantaged populations.**

I. Introduction

In 2009, only 15% of undergraduates enrolled in US 4-year engineering programs identified themselves as black or Hispanic.[1] This is out of proportion with the 18-24 year old age group in the general population which is comprised of 34% blacks and Hispanics.[1] These statistics are troubling when considering the rapidly evolving job market in the U.S., which places a premium on a skilled and knowledgeable workforce.[2] This raises concerns about leaving a portion of the population under-represented in our skill-based economy.

Increasing diversity in the science, technology, engineering, and mathematics (STEM) fields can reverse trends like these. Many universities have established outreach programs in an attempt to address this need, often placing an emphasis on targeting minority and female student populations. Typically K-12 students are brought to the campus for camps or seminars, or alternatively, K-12 educators are trained by university faculty and staff.[3] These programs often attract students and parents who have a baseline interest in STEM. However, such programs may not reach students who are unaware of the STEM fields and would benefit the most from exposure to the possibilities of what the STEM fields offer.

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II. Literature Review

Using enhanced context techniques to teach classroom topics, defined as teaching methods that link new material to topics in which students already have an interest and intrinsic knowledge, is much more effective than other instructional strategies.[4] Introducing new concepts while connecting the material to the prior knowledge of the students in areas about which they are passionate can stimulate deeper understanding and retention for the learner.[5] This instructional approach not only informs the student on a new topic, but also reinforces their previous knowledge and empowers the student by highlighting expertise they unknowingly possess. An example of this expertise are the complex geometric patterns that are present in the street art that is produced by young graffiti artists.[6] These young artists utilize mathematical and geometric concepts in their art but neither they nor the traditional education system recognize the relationship between the street art and the classroom material. This intrinsic understanding for scientific and mathematical concepts that goes unrecognized by the educational system is termed "hidden capital."

Groups have used the idea of hidden capital to demonstrate the relationship between the social and cultural practices in minority populations and STEM. In one case, a set of Culturally Situated Design Tools was developed in which fractal geometry can be used to design new cornrow hairstyles and graffiti is used to teach the Cartesian coordinate systems.[7], [8] Another group used hidden capital in relation to sports, using the biology, math and physics underlying the game of baseball to demonstrate STEM concepts at a summer camp for young baseball players in underprivileged communities.[9] Both of these approaches are novel and important because they translate the STEM curriculum to topics in which minority students have a vested interest. Teaching with hidden capital exposes students to new educational concepts while simultaneously showing how STEM can enrich activities that they are already passionate about. These techniques have the potential to reach a population of students who are currently disenfranchised by the common model of STEM outreach such as robotics competitions, STEM camps and university engineering day events.

III. Biomedical Engineering as a Vehicle for Outreach

The most effective teaching strategies are those which engage students in topics in which they have a previous,

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intrinsic understanding.[4] The best strategies require igniting or incorporating students' passions and interests while also providing students with a hands on, authentic learning experience.[4], [5] Engineering is an ideal vehicle in the K-12 environment for these techniques because, by its very nature, engineering is the application of math and science for the purpose of solving real world problems.[2] Biomedical engineering, however, has the potential for a high level of effectiveness because it can utilize the hidden capital present in students' intrinsic interest and understanding of the human body. Biomedical engineering research is centered on investigating and solving problems in human health. Biomedical engineers can utilize the hidden capital in human health by first informing the student on STEM principles by explaining observed phenomena in the context of the underlying STEM principles and then enrich the students experience by suggesting solutions based on the mechanisms exposed using scientific techniques.

We have developed a novel teaching module to connect K-12 underrepresented minorities to STEM fields. The module utilizes the scientific method to examine the biomechanics of the slam dunk in basketball. The slam dunk, an example for the module is found in Fig. 1, is one of the most exciting plays in basketball and a player's ability to dunk is seen within peer groups as an indicator of that player's skill and potential.

The slam dunk module, called "Science of the Slam", is unique in that it explores the biomechanics that underpins a play which is seen as the ultimate feat of basketball ability. Ultimately, it gives players unique insights on how to use biomechanics to improve their game. The connection between science and sports achievement makes this module compelling to an audience that is typically uninterested in traditional STEM outreach activities. For this module, the relationship between the vertical ground reaction force generated by the athlete during jumping and the jump height is examined using two force plates. Older basketball players who are able to do a slam dunk provide the test subjects for the module.

IV. The Science of the Slam

The "Science of the Slam" module begins with a short discussion about using science and math to describe things that students care about in the natural world. This leads to the application of the scientific method to discover what makes someone good at performing slam dunks. Students participate in an open discussion on what qualities great dunkers share. The answers range from creativity of movement while airborne, vertical jump height, and even how hard the player slams the ball through the hoop.

The discussion concludes with examples demonstrating that science is a powerful tool to measure and quantify events as a means to learn more about them.

Upon discussion—and with some gentle guidance—students ultimately determine that the vertical jump height of the player is the easiest parameter to measure. However, the leader of the module then informs the group that he "forgot" his camera and so taking pictures to compare jump height is not an option. The students are told that they can use only the biomechanics lab equipment on hand, which consists of force plates. There is now a quandary and students often ask how the force plate can be used to determine jump height (and the best dunker). The students brainstorm and arrive at the conclusion that they can measure how hard the player pushes off the ground. The harder they push, the higher they should jump and the better the dunk should be.

At this point, the steps of the scientific method are presented to the students and related to the current topic of quantifying the properties of a good dunk. Many students are often familiar with the scientific method, but this will be its first application to something that they care about outside the classroom. The students then test the hypothesis that the player who is the best at performing the slam dunk will have the highest ground reaction force.

Figure 1. A volunteer performing a slam dunk during Science of the Slam

TABLE I. PROCEDURE FOR SLAM DUNK EXPERIMENTS

Step	***Description***
1	The basketball players line up and are asked to perform the best slam dunk that they can.
2	Student spectators form groups based on what player they think had the best dunk.
3	The basketball players are placed into a bracket with seedings depending on their number of fans.
4	The competing players stand on a force plate and perform a two foot standing jump as high as they can while being cheered on by their respective fans.
5	The player who reachs the highest value for force is acknowledged and they move into the next round.
6	The competition countinues until the bracket is complete and a winner is crowned.

Table 1 describes the procedure for performing the experiment to test the hypothesis of that the best dunker will generate the highest ground reaction force. When the module has been used, the heaviest player "wins" the bracket every time relative to the shorter and lighter competitors in the dunk contest. The students are then polled to see if they think the heaviest player is the best dunker in the group. With the exception of a few kind and sympathetic students, they usually say no. The hypothesis is false but it is stressed at this point that often scientists do not succeed on the first attempt when modeling phenomena. The leader then works with the students to revisit the hypothesis in light of the first experiment's results to explain what changes can be made to the model to make it more accurate.

To demonstrate, the heavy "winner" stands on one force plate and the best dunker (by general consensus of the audience) stands on the other. The students are asked to look at how the body weight of the two athletes relate to each other. Discussion ensues until the students arrive at the idea that the heavier player has a considerably larger ground reaction force even while standing still on the plate. The heavier player must use more force in order to compensate for the additional weight he carries. Only by applying more force relative to a lighter player can the heavier player get airborne.

In this way, students are introduced to the concept that ground reaction force is proportional to the weight player and the force with which he pushes off the ground during jumping. This allows the students' earlier hypothesis to evolve to something more accurate. The new hypothesis becomes that the player who is the best at performing the slam dunk will have the highest ground reaction force relative to his resting body weight. This hypothesis is then tested by performing one more measurement of force generation between the competitor who won the dunk popularity contest and the player who generated the most force. The better dunker generates more normalized force and he is crowned the winner of the contest. The experiment showed that dunking ability is linked to generating force relative to body weight. As such, this suggests that dunking skill can be improved by either increasing a player's ability to push off the ground or by losing weight. This conclusion stimulates a discussion by the students about what steps a player to can take to maximize this ratio. A comparison is then made between the structure and function of fat tissue versus muscle tissue. This initiates a discussion on training techniques that will allow the student to lose weight by reducing fat while increasing their ability to generate force by increasing muscle.

V. Discussion

Each time this module has been used, interested students have prevailed upon the leaders to stay after the end of the allotted time to answer science questions and hear suggestions for future work. Although no formal data have been collected on the results of the program to date, anecdotal evidence from student feedback has been very positive and students have asked about the application of other scientific concepts to sports. The module has recently been requested by a variety of community groups in the authors' area.

This novel STEM outreach program engages the interest of students who are often unreachable through typical STEM outreach programs. By using the hidden capital for urban youth found in basketball, the Science of the Slam module connects scientific inquiry to athletic performance for student-athletes. This approach not only informs the students on the specific concepts that are covered in the module, it also highlights the intrinsic knowledge that the students already possess about science through their understanding of sports. Many of the students already grasped the fundamental relationships that were examined in the Science of the Slam. The module translated their intrinsic understanding of basketball into scientific concepts and allowed them to explore the applications of the scientific method within the context of becoming a better basketball player. This changes the STEM fields from a daunting scholastic subject to a tool of empowerment for the student to become a better athlete. This allows the Science of the Slam to target underrepresented groups who are typically unreachable in traditional outreach programs.

VI. Conclusion

We were able to create a compelling introduction to the STEM fields for an audience that is disenfranchised by typical STEM outreach programs and we tapped into this new, underrepresented population by finding a topic that would find a passionate audience within our target demographic. We tailored the content of the module to first validate the intrinsic knowledge that the audience has in the subject. Critically we transitioned this intrinsic understanding into scientific concepts and showed how the STEM fields can enrich the students' abilities and experiences within the interest area of their choosing.

Via this process, it is possible for educators to develop a module based on their own work. It is a matter of educators finding what is compelling about their own work and identifying an underrepresented group that would benefit and share a similar interest. It is not necessary to relate the entire scope of a research project into an outreach program, only to utilize a specific facet of the program that could hold tap into the interests of an underserved group. Biomedical engineering research is full of scientific work that can be linked to hidden capital that is found within the populations that are underrepresented in the STEM fields. We hope to stimulate the interest of other research groups to pursue outreach activities utilizing the Science of the Slam as a framework.

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