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Solutions based on Biomimicry for Personalized Health

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Prospectus

Health Science is a course designed to educate New Haven public school students about the problems and possible solutions in the healthcare industry. As a teacher of Health Science at Metropolitan Business Academy, creating an engaging, real-world lesson combined with the skills of critical thinking and problem solving is the ultimate goal. The Personalized Health unit will incorporate the growing field of personalized health, from diagnosis to prevention, as well as the practice of biotechnology and engineering through the use of biomimicry. Students will be expected to design a new technological advancement to solve a health problem. The students will create a simulation and biomimetic prototype based on the natural world after completing the engineering design process. The students will design a pitch and marketing campaign considering the limiting factors of economics, sustainability and accessibility while presenting the idea to various validators in a 'Shark Tank' format. The pitch will need to be creative and include how the prototype will solve a health problem using biomimicry.

As a teacher in the city of New Haven, it is my duty to develop the skills necessary for jobs in the healthcare industry. The city of New Haven is now becoming a hub for Biotech companies. Throughout the unit, the students will be exposed to the latest biotechnological practices. One of the key components is the sequencing of the genomes of pathogens and how to apply the knowledge to developing diagnostics and cures. I expect the students to gain an understanding and be able to apply polymerase chain reaction, recombinant antigens and monoclonal antibodies to molecular diagnostic methods used in personalized healthcare. I want the students to gain an understanding of how vaccines are used and administered. The focus should especially be on new technologies for easier transport and access and increasing equitable healthcare worldwide.

Unit Teaching Strategies

Next Generation Science Standards (NGSS) are a set of standards that have been adopted and currently being implemented in the state of Connecticut. One of the major aspects of NGSS is the engineering process. The foundation in engineering design allows students the opportunity to engage in and help to solve societal problems and challenges such as healthcare. Below are the process, requirements and standards from the NGSS website (Nextgenscience.org).

Engineering Design Process (Nextgenscience.org)

Defining the problem (IDENTIFY & EXPLORE) at the high school level requires both qualitative and quantitative analysis. For example, the need to provide food and fresh water for future generations comes into sharp focus when considering the speed at which world population is growing, and conditions in countries that have experienced famine. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering.

Developing possible solutions (CREATE) for major global problems begins by breaking them down into smaller problems that can be tackled with engineering methods. To evaluate potential solutions, students are expected to not only consider a wide range of criteria, but to also recognize that criteria need to be prioritized. For example, public safety or environmental protection may be more important than cost or even functionality. Decisions on priorities can then guide trade off choices.

Improving designs (REFINE & SHARE) at the high school level may involve sophisticated methods, such as using computer simulations to model proposed solutions. Students are expected to use such methods to take into account a range of criteria and constraints, to try and anticipate possible societal and environmental impacts, and to test the validity of their simulations by comparison to the real world.

Unit Content Objectives

By the end of twelfth grade students are expected to achieve all four High School Engineering, Technology and Applied Science (HS-ETS) performance expectations (listed individually below) related to a single problem in order to understand the interrelated processes of engineering design. These include analyzing major global challenges, quantifying criteria and constraints for solutions. Students are expected to break down complex problems into smaller, more manageable problems, evaluating alternative solutions based on prioritized criteria and trade-offs, and using a computer simulation to model the impact of proposed solutions. While the performance expectations shown in high school. The process of Engineering Design couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices that lead to the performance expectations. In other words, the unit will incorporate many other practices explained below during the lessons.

HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

The performance expectation will allow for students to explore global health problems while analyzing data on the World Health Organization website. It is important to expose the students to metrics looking at trends both worldwide and locally. The metrics will be used to analyze the constraints of possible solutions and balance the needs and wants of the local community. The utilization of gapminder tools, the students will gain the opportunity to research qualitative and quantitative data. The study of demography will allow for students to understand the various ratios to determine is the health problem is a societal need.

HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

The performance expectation listed here will incorporate the use of biomimicry once the solution is broken down into smaller pieces. For example, in the article Medicine's Newest Biomimicry Inspirations, the sandcastle worm is being mimicked to develop an adhesive that could be used to potentially mend broken bones. Medical professionals needed to create better access to ways of healing broken bones. The solution was broken down (no pun intended) to an adhesive. As a medical breakthrough, it would allow an easier and quicker means of healing broken bones.

HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

The performance expectation above allows the students to assess their solution as well as the solutions of other students in the class. There will be an increased emphasis on the analytics discussed during HS-ETS1-1. In the lecture series by Anjelica Gonzalez, the factors to consider when assessing the importance of a new technology are impact, appropriateness, burden, feasibility, knowledge gap, and indirect benefits. This is basically a risk assessment where students will weigh direct or indirect consequences to the new technology of both their own prototypes or those of their classmates.

HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The share portion of the design process will facilitate the performance expectations listed above. Giving students the ability to create and share a simulation and test their solution to the real-world problem. The computer simulation with work in parallel with the prototype.

Personalized Health

Personalized Health is a growing field not only in developed countries like the United States of America, but also developing countries. Generally, personalized health is considered an area of great technological advance. The purpose of the unit is to have students think about the availability of personalized health in industrial versus developing countries. The question remains, how do we increase access to the growing field and type of personalized health care that is available? In a Ted-Ed video, Steve Johnson talks about how technology that works in the United States may not be feasible in a third world country. The basis of the premise resides in the fact that engineering usable technology must take into consideration the end-user. I

will prepare my students to complete an assessment of personalized health focused needs and provide students the materials needed to navigate development of their engineering and innovation.

The process of diagnosis and the development of preventative medicine, vaccines or treatments available for all industrialized and developing countries is the overlying premise for the Personalized Health Unit. The students will generally focus on the problems of malaria, HIV and tuberculosis. According to a 2016 study by the World Health Organization, malaria, HIV and tuberculosis are in the top 10 causes of death among low-income countries (who.int) but not even listed among the top 10 causes of death among upper-middle and high-income countries. It is obvious that the technology is available to prevent these diseases, but it is not accessible to low-income populations. The application of personalized health to preventative medicine is the main goal. Once the idea for the solution is created, the students will need to use biomimicry to guide the solution. Biomimicry is utilizing the natural worlds solutions to problems and applying them to personalized health issues. Overall, the unit will encompass the various ways biotechnology, engineering and biomimicry can be used to not only prevent and diagnose health problems, but also to cure the multiple epidemics facing the world population.

Futuristically, Personalized Health has the potential to develop into an effective tool for patient focused preventive medicine. With easily accessible DNA testing and developing technologies in prevention, researchers suggest that personalized preventative therapeutics may be implemented as early as 2050. Personalized preventative medicine could prevent oncoming epidemics and primary causes of death with accessible solutions.

Personalized Health is a comprehensive and individualized approach to preventing, diagnosis and treating disease. The biotechnological advances increase the successful implementation of personalized healthcare but the access and availability continues to be limited. The unit will be comprised of components of personalized healthcare examples that are currently being utilized and how to design innovations to create more access to the technologies. Developing accessible personalized healthcare to low-income populations will be one of the parameters for the students in my Health Science class.

Biomimicry

Biomimicry is quickly developing as an emerging practice in the engineering and design process. According to the Biomimicry Institute, the practice of biomimicry is defined as intentionally trying to design products or processes in ways that mimic the biological and natural product and process as closely as possible. Natural processes have been solving engineering problems for more than 3.8 billion years. Utilizing the experience of the natural world to solve the problems facing mankind and the development of personalized health is a no brainer. As an example, natural selection has enabled bacterial to compete for survival longer than human beings have. Many other life forms, from plants to insects, have specialized components that allow for successful survival. The specialized components are often at the cellular level and with advances in biotechnology, students could apply successful strategies to solve healthcare challenges.

Utilizing step one, defining the problem, of the engineering design process from NGSS is crucial to Biomimicry. Once the problem has been defined, the students will explore solutions by observing the natural world and thinking about its wonders. This will allow students to generate ideas to help them solve healthcare problems.

One example that has been recently developed is technology of a needle based on the mosquito's proboscis. The female mosquito has developed a mostly painless way of sucking blood. According to the research by Kong XQ, the success of the mosquito is based on the design of the proboscis but also the force and frequency of the penetration. As more scientists studied the evolved biological successes of the mosquito, the more they realized that a better designed needle could lead to a less painful way of drawing blood, distributing vaccines and other medicines; making them more viable.

"The reason we look at nature for cues is because nature has been through so much evolution to discover the simplest and most efficient methods," Bharat Bhushan, a professor of Mechanical Engineering at Ohio State, told Digital Trends. "In this work what interested us was the way that mosquitoes bite, since they are able to do this for several minutes without us feeling a thing. We wanted to use this to see if we could develop a painless microneedle."

Bhushan makes an excellent point in regards to leaning on natures evolutionary solutions to complex problems. Another example was featured on CBS Sunday Morning, while observing the phenomenon of a frog capturing an insect, mechanical engineers realized the adhesive on the tongue of the from saliva was able to withstand seven times the force of gravity. As a mechanical engineer specializing in fluid mechanics, the aspiration is to develop a stronger adhesive using biomimicry.

One of the most compelling reasons for using biomimicry to develop human health solutions is sustainability. Sustainability is one of the main components in successful innovations. Sustainability encompasses multiple aspects. Environmental sustainability needs to be considered, especially with the negative impact humans are currently having on the climate, When Biomimicry is used, there is an increased potential for great environmental sustainability because in nature, nothing is wasted. As humans work to solve major health problems in both the industrialized and developing world, we must consider sustainability with growing concerns about climate change. As the study of biomimicry becomes more popular, the realization that nature has solved problems in the most efficient way. John Elkington described The Triple Bottom Line as an accounting framework that incorporates the three dimensions of people, planet and profits. The three P's of the Triple Bottom Line are difficult to measure but should be kept at the forefront of all engineering and design decisions.

Application of Systems Engineering

The application of Systems Engineering in the process to develop health solutions is imperative to successful innovation and design. With this background, I will now describe the process a systems engineer undertakes in a health care improvement project. There are six fundamental steps, which are conducted iteratively. Each of the six will be briefly described.

Developing an understanding of systems engineering will allow the students to think about the big picture for their innovations. Wikipedia defines systems engineering as an interdisciplinary field of engineering and engineering management that focuses on how to design and manage complex systems over their life cycles. At its core, systems engineering utilizes systems thinking principles to organize this body of knowledge. The individual outcome of such efforts, an engineered system, can be defined as a combination of components that work in synergy to collectively perform a useful function.

1. Define system purpose and scope, specify required functions and resource types, and develop relevant performance measures along with desired performance thresholds.
2. Specify, collect, and develop required data through data collection methods.
3. Design, validate, and verify appropriate system models - This involves selecting the right modeling tools, building and validating the model.
4. Use the model to learn about system behavior to find the best design alternative. The engineer often develops appropriate experiments for studying the model and analyzing the results.
5. Use the results of step 4 to determine how to configure the system for best performance. This involves specifying equipment requirements, staffing levels and patterns, scheduling procedures, workflows, and so forth. Sensitivity analysis is also important to determine how system performance will be affected by perturbations to nominal conditions.
6. Develop implementation and evaluation plans and coordinate their performance.

With these six steps in mind, some of the most important engineering methods are listed below with a brief explanation. Many of these originate from the discipline of Industrial Engineering, which is often synonymous with Systems Engineering.

Classroom Activities

The unit will begin with the NGSS science and engineering practice of Asking Questions and Defining Solutions. Using the question formulation technique to engage the students with both local and world-wide problems in healthcare. It is important that this process is authentic and organic. The brainstorm will consist of any major human health problem the students can think of. Some of the factors to be considered should include, but are not limited to: economics, research, implementation, troubleshooting, accessibility, and equitability. Once the brainstorming is complete the question formulation technique will allow them to turn topics into questions. The questions will be vetted by both peers and teachers, the students will choose a select few to propose as possible questions to answer and lead them through defining solutions. Finalized questions will lead the students to and through the first step of the Engineering Design Process which begins with identifying and defining the problem.

Using a finalized question to navigate through the engineering design process, the students will begin the interview and research steps to develop possible solutions. This process will incorporate the NGSS science and engineering practice of Using Mathematics and Computational Thinking. The students will evaluate quantitative and qualitative data while examining the constraints. Once the research and analysis of the data has been completed the students will begin the second part of the Engineering Design Process of developing possible solutions.

Once a list of possible solutions have been compiled, the students will begin researching possible ways that solution is already in place in nature. The Biomimicry component will drive the design process for the personalized health solution. The students will then develop both a computerized and physical prototype.

Lastly, the students will begin the third step of the Engineering Design Process by improving designs using the NGSS science and engineering process of Constructing Explanations and Designing Solutions. The students will present their first prototype to other groups using claim evidence and reasoning. The other groups will

listen to the idea and think about questions and critiques of the design. Not only does this allow the students to receive critiques and answer questions about their design, it also allows for them to see other designs to promote more ideas. As the students create their innovations and prototypes there will be opportunities for peer review and feedback as well as the use of computer simulations to test and predict the effectiveness of their biotechnological innovation.

Resources for Teachers

Teachers should start by reviewing the NGSS website with specific focus on the four performance expectations. When looking at the performance expectations, take note of the science and engineering practices, disciplinary core ideas and cross cutting concepts. Lastly, I highly recommend looking at the evidence statements which detail the observable student performances. By analyzing the standards first, the teachers will be able to clearly define and implement purposeful lessons. To gain a better understanding of personalized medicine, teachers should look at the 'Health 2050' article by Melanie Swan. Next, the teachers should review the article 'Applying Systems Engineering Principles in Improving Health Care Delivery' in order to see exactly how the engineering design process is directly applied to health. Lastly, I recommend teachers to browse biomimicry.org because there are multiple resources and lesson plans to help with the implementation of this unit.

Resources for Students

Utilize the CBS News video 'The Fascinating World of Biomimicry' with the students to introduce the use of biomimicry within their engineering design. Students should reference the World Health Organization website during the statistical analysis portion of their research.

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Appendix: Implementing District Standards

The NGSS standards that are utilized in the personalized health unit begin with the science and engineering practices taken from nextgenscience.org appendix F. Asking questions and defining problems are at the core of this unit. Developing and using models are part of the prototype design. Analyzing and interpreting data is part of the research and statistical analysis of major health problems. Using mathematical and computational thinking occurs during the computational design and cost analysis. Constructing explanations and designing solutions is consistently practiced throughout the unit. Engaging in argument from evidence and communicating information are both science and engineering practices that will be used when presenting their solutions during 'Shark Tank'.

The NGSS standards for disciplinary core ideas are all from the engineering, technology and applied science performance expectations. HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The NGSS standards for cross cutting concepts in the personalized health unit are taken from the nextgenscience.org appendix G. Observing patterns to formulate relationships with data and the use of biomimicry to solve problems. Cause and effect concepts will be represented in multiple unit activities. The concept of systems and system models is very important in the personalized health unit because it allows the students to visualize the entire impact of their innovation. Structure and function cross cutting concept is vital to the biotechnology and understanding the intricate components to both the problem and the solution.