Hands-on and Minds-on Learning of Science using a Microbial Fuel Cell

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Introduction

Microbial fuel cells (MFC) use the biochemical processes of live microbes to generate an electric current. Understanding how it works requires integration of concepts across chemistry, biology and physics. MFCs have very low power output and thus have limited practical applications. However, they have many functional parameters to manipulate and are thus ideal for design-based inquiry (DBI) learning activities. Here, students are challenged to construct improvised MFCs to meet specific goals. DBI can push students to apply their knowledge/skills while fostering deep understanding across STEM disciplines.

Design-Based Inquiry Learning Activities

A key aim in our project was to see if students would inform or base the design and construction of their MFC on "science" or simply make arbitrary choices. The project also hopes to find out it students will approach the hands-on iterative experimentation and design work systematically or through trial and error.

Another key aim was to examine their learning across the conceptual, epistemic and social learning domains of science education (Duschl, 2008), in the service of developing authentic scientific literacy, as opposed to merely accumulating content knowledge.

A total of 77 Secondary Two students in 2 cohorts from a government-aided co-educational school in Singapore participated in a programme of 10 weekly sessions (1.5 to 2 hours each) co-developed by the research team and experienced science teachers from the school. Students were given an introduction to MFCs and then worked in small groups to conduct guided, then open inquiry experimentation to find optimal combinations of reagents and conditions. They would then iteratively design-and-build MFCs to meet several design challenges that were given near the start of the programme.

The inter-group competition inherent in such challenges was highly motivating, as students sought to attain the highest voltage, best longevity, or the ability to light up the most light-emitting diodes (LEDs) during the "MFC Challenge" during the final session. Students were also engaged by the context of alternative energy sources, environmental and sustainability issues.

Independent and Self-Directed Learning

With teacher support in the initial stages and as scaffolds were progressively withdrawn, students were able to formulate and conduct their own investigations to determine optimum parameters for MFC function. With the teachers and the research team only acting in advisory and supervisory roles, the students could cooperatively tinker with, design and construct functioning MFCs out of items such as drink bottles and disposable food containers, that outperformed kit-based MFCs. A kit-based MFC using the standard reagents produces an open-circuit voltage of around 0.5V, but one team in each cohort created single-cell MFCs that produced in excess of 0.87V, and even more impressive output in batteries of MFCs connected in series. 15 of 18 student groups created improvised MFCs that surpassed the reference 0.5V from the commercial kit-based MFC.

It was commendable that many of these young students were able to apply "science" to experimental-design tasks, engineering-design tasks, and to solve the many complex cross-disciplinary problems that were embedded in the design of the programme. They demonstrated learning and skills development, especially in the desired epistemic and social domains. These included the ability to interpret authentic but "messy" data from the collective experimentation done, in order to make evidence-based decisions about choice of and concentrations of reagents for optimal output, and the physical design of their MFC prototypes.

Students engaged readily in self-directed learning, were actively cooperating and collaborating in solving problems, and generally acting as student-scientists and student-engineers. An overwhelming number of students reported that they enjoyed the programme, with quite a few of them stating that they hoped for greater use of such an approach in school science. The MFC programme was thus able to achieve the desired "minds-on" learning and a broader development of important aspects of scientific literacy.

Reference

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. Review of Research in Education, 32, 268–291.

How to Cite

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