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Fostering Engagement and Inclusion in CURE for Hong Kong health professional undergraduate students: The Impact of the Design2Data (D2D) Approach on Student Attitudes and Contributions to Scientific Research

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Abstract

This study explores the impact of the Design2Data (D2D) approach on student attitudes, dispositions, and sense of belonging within Course-Based Undergraduate Research Experiences (CURE) in Hong Kong. By examining student feedback and engagement, we found that the D2D approach significantly enhances positive attitudes and fosters an inclusive environment, which is essential for effective participation in research activities. Students reported higher levels of motivation and persistence, leading to meaningful contributions to scientific research. Additionally, follow-up discussions indicated an increased awareness of the significance of AI in the field of protein structure and design, highlighting the importance of addressing current trends and issues in the discipline. This supportive educational framework not only enriches students' academic experiences but also equips them with vital skills and mindsets for future success in their academic and professional endeavours.

Keywords: *Course-based undergraduate research experience (CURE); Design2Data (D2D); Health professional undergraduate students*

1. Introduction

Course-based undergraduate research experience (CURE) is an innovative pedagogical approach that integrates research experiences into the undergraduate curriculum. This method enables students to engage in authentic research projects as part of their coursework, fostering

a deeper understanding of scientific inquiry and enhancing their critical thinking and problem-solving skills. By participating in CURE, students not only gain valuable hands-on experience but also develop a sense of ownership over their learning, which can lead to increased motivation and retention in their academic pursuits.

In Hong Kong, however, implementing CURE presents unique challenges (Yau et al., 2022; Yau et al., 2024). As a relatively new approach in this educational context, institutions face difficulties in adapting established models. Faculty members may encounter obstacles in designing research projects that effectively align with course objectives while accommodating the diverse abilities and backgrounds of students. Additionally, limited resources, time constraints, and the need for interdisciplinary collaboration can complicate the execution of successful CURE initiatives.

In this study, we summarize the experiences of adapting various strategies from well-developed CURE projects in the USA and modifying them for use in the Hong Kong setting. By recognizing both the potential rewards and the obstacles associated with course-based undergraduate research, we aim to provide insights that can help educators create enriching learning environments tailored to the unique context of Hong Kong, empowering students to thrive as researchers and critical thinkers in their fields.

2. Methodology

This study employed a systematic approach to investigate CURE models from various universities in the United States, with the goal of adapting these strategies for implementation in the Hong Kong educational context. The methodology consisted of the following steps:

1. Identification of CURE Projects: We began by utilizing CUREnet (networking among faculty developing, teaching, and assessing CURE) and CURE related grants funded by universities or US government, a comprehensive network dedicated to course-based undergraduate research, to identify existing CURE projects and teaching models at various universities across the USA. This platform provided valuable insights into a range of successful CURE implementations.
2. Exploration of Collaborative Opportunities: After identifying potential CURE projects, we sought opportunities to engage with these institutions. This involved reaching out to faculty members and program coordinators to learn about their CURE initiatives, the challenges they faced, and the strategies they employed to enhance student engagement and learning outcomes.
3. Contacting Selected Institutions: Through our outreach efforts, we successfully established contact with two universities that had well-developed CURE programs. We arranged for discussions and, where possible, virtual visits to gain a deeper

understanding of their operational frameworks, assessment methods, and best practices.

4. Comparative Analysis: We conducted a comparative analysis of the selected CURE models, focusing on aspects such as project structure, faculty involvement, student engagement strategies, and assessment criteria. This analysis allowed us to identify key elements that could be adapted for the Hong Kong setting.
5. Implementation in Hong Kong: Finally, we adapted the insights gained from the comparative analysis to develop and implement CURE initiatives in the Hong Kong educational context. This involved modifying project designs, incorporating local resources, and considering the specific needs and backgrounds of Hong Kong students.

3. Results and Discussion

3.1. CURE Project Identification and Collaboration Process

After the screening process around 20 US universities, we had the opportunity to join briefing sessions for two CURE projects, allowing us to further explore the opportunity to join their workshops. The two projects are Design2Data (D2D) (Carlin et al., 2017), led by the Siegel Lab at UC Davis, and Surveillance and Monitoring of Amphibian Pathogens (SNAPs), supported by the US Geological Survey and Environment and Climate Change Canada (Perez Jennifer, 2023). Details for implementing the D2D project, including the lab manual and workflow, are available at the following D2D Lab Manual webpage (2022). Information on running SNAPs in the classroom can be accessed here: SNAPs Classroom online Resources (2025).

3.2. Comparative Analysis

The nature of these projects is markedly different. D2D focuses on investigating the sequence-structure-function relationship of proteins. Through this initiative, students engage in a research workflow that mirrors cutting-edge biotechnology training, equipping them with valuable skills that are in high demand by employers. A distinctive feature of D2D is its integration with the RosettaCommons protein modeling community, which utilizes student-generated data to enhance functionally predictive enzyme-design algorithms.

In contrast, SNAPs addresses the emerging threat posed by the fungal pathogen *Batrachochytrium salamandrivorans* (*Bsal*), which endangers salamander populations in Europe and North America. Although *Bsal* has not yet been detected in North America, its potential introduction makes early detection crucial. The SNAPs initiative leverages student involvement to implement ongoing and cost-effective *Bsal* surveillance, integrating this critical work into the undergraduate curriculum. This project is part of the Surveillance Working Group of the North American *Bsal* Task Force and highlights the importance of broad and long-term

monitoring efforts, despite the inherent challenges of surveillance. We formed focus groups with local university faculty and experienced CURE teachers from the USA to discuss the pros and cons of these projects for urban university students, particularly in Hong Kong.

SNAPs project presents unique advantages and challenges for these students. On the positive side, SNAPs actively engage students in critical ecological research that addresses the urgent threat posed by the fungal pathogen *Bsal* to amphibians. However, number of SNAPs projects at USA have found no *Bsal* in their samples, leading to disappointment among students. While *Bsal* can be found in the wild areas of Hong Kong (Chen et al., 2023), this hands-on involvement fosters a sense of responsibility and civic engagement, allowing students to contribute to real-world conservation efforts. By integrating surveillance into the undergraduate curriculum, students can apply their learning in meaningful ways, enhancing their educational experience. Additionally, the project promotes teamwork and collaboration among students, fostering a supportive learning environment. On the downside, students must navigate a complex approval process that includes obtaining licenses for handling wild animals. This paperwork can be time-consuming and may deter participation. Moreover, students may need to spend extended periods outside the university to conduct fieldwork, with limited opportunities for follow-up experiments, as identifying microorganisms requires sending samples to the U.S. for analysis. Sending the samples add further hurdles to the identification process and potentially delaying results.

In contrast, D2D offers several benefits for urban university students. It provides hands-on experience in protein biochemistry, equipping students with valuable laboratory skills and knowledge in a high-demand field. The project aligns with current biotechnology trends, making participants more attractive to potential employers. Additionally, collaboration with the RosettaCommons protein modeling community allows students to network with professionals and gain insights into the broader scientific landscape. Furthermore, D2D encourages interdisciplinary learning by integrating concepts from biology, chemistry, and computer science, fostering a comprehensive educational experience. Nonetheless, there are challenges associated with D2D. The project can be resource-intensive, requiring access to specialized equipment and materials.

3.3. Implementation in Hong Kong universities

We integrated the D2D elements into the practical sections of the course related to cell biology and biochemistry for second-year undergraduate students. The protocol is largely the same as that provided by the Siegel Lab; however, due to the challenges of shipping single-strain DNA templates for mutation from the USA to Hong Kong, we purchased the plasmids with the desired mutations directly from local biotech companies. A total of 42 students completed the feedback questionnaires via MS Forms, and the results are presented in Figure 1.

Figure 1. Student Feedback Results on the Integration of D2D Elements in Cell Biology and Biochemistry Practical Sections of Hong Kong health professional undergraduate students

In general, the students' feedback was very positive across all five areas addressed. They expressed high expectations to (1) build knowledge and skills, (2) develop attitudes and dispositions, (3) cultivate a problem-solving mindset and research interest, (4) feel included and have a sense of belonging, and (5) explore or clarify their educational and career pursuits for this CURE activity.

It is noteworthy that, following the activity, more students reported feeling a decrease in their sense of achievement despite acquiring knowledge and skills. This may be attributed to the relatively straightforward nature of the experiment, which may not have posed significant challenges for them. In contrast, students indicated that their achievements in cultivating a

problem-solving mindset, developing research interests, and exploring or clarifying their educational and career pursuits met their expectations.

Interestingly, a larger number of students recognized that the D2D approach positively influenced their attitudes and dispositions, while also fostering a sense of inclusion and belonging. These elements are particularly crucial for CURE students, as positive attitudes and dispositions enhance engagement, motivation, and persistence in research activities. When students feel included and have a sense of belonging, they are more likely to participate actively, collaborate effectively, and make meaningful contributions to scientific research. This supportive environment not only enriches their educational experiences but also promotes the development of skills and mindsets essential for success in their future academic and professional pursuits.

In a follow-up face-to-face discussion, students also expressed their awareness of this year's Nobel Prize winner, David Baker, who focused on computational protein design, underscoring the significance of AI in recent years, which greatly enhanced their interest and awareness of the importance of participating in this D2D CURE activity.

3.4. Limitations of the Study

This study has several limitations that should be acknowledged. The sample size of students and institutions involved may limit the generalizability of the findings, as the results may not fully capture the diversity of experiences across different universities. Additionally, the assessment primarily focused on short-term outcomes, such as immediate changes in knowledge, skills, and self-efficacy, without exploring the long-term impacts on career progression, research contributions, or sustained interest in STEM fields. Furthermore, differences in the implementation of CURE activities across institutions, such as variations in teaching methods, resources, and faculty expertise, may have influenced the outcomes, making it challenging to attribute the observed impacts solely to the CURE model. Finally, some findings rely on self-reported data from surveys and focus group discussions, which are subject to potential biases, such as social desirability bias and recall bias. Future studies should consider incorporating objective measures of student performance and engagement to address these limitations and provide deeper insights.

3.5. Perspectives and Challenges

A key perspective for the future is the development of interdisciplinary CURE projects that integrate health sciences with emerging fields such as data analytics and AI. These interdisciplinary approaches reflect the evolving landscape of healthcare, which increasingly demands expertise spanning multiple domains. Introducing such projects would not only enrich students' learning experiences but also better prepare them to address the complexities of

modern professional environments. However, to ensure the success of these initiatives, it is essential to consider resource constraints, such as funding, faculty expertise, and infrastructure, which may limit the scalability and impact of interdisciplinary CURE programs.

To create a sustainable and impactful framework for CURE in Hong Kong, universities should also prioritize the development of robust and standardized evaluation mechanisms. These mechanisms could include longitudinal tracking of student outcomes, such as research competencies, academic achievements, and career trajectories, to assess the long-term effectiveness of these initiatives. Addressing the limitations of relying on self-reported data, future evaluation efforts should incorporate objective measures of student performance and engagement.

Furthermore, offering faculty development workshops on designing, implementing, and assessing CURE programs would empower educators to overcome challenges related to variability in implementation. This would also enable the creation of consistent and scalable models across institutions. By addressing these perspectives and limitations, Hong Kong universities can foster a more inclusive and impactful research environment for undergraduate health professional students. This approach will equip them with the interdisciplinary skills, practical experiences, and professional insights necessary for future academic and career success.

4. Conclusion

In summary, implementing CURE provides a practical and effective way to engage health professional undergraduate students in research while addressing the diverse needs of individual projects. Given the manpower required for personalized research experiences, integrating CURE elements into the practical sections of undergraduate courses is a more feasible solution. We hope that disseminating our approach will assist those looking to incorporate CURE elements into their curriculum in identifying effective strategies for their specific context.

In addition, the D2D approach not only facilitates the study of enzyme structure and model prediction for beta-galactosidase but can also be adapted to investigate various enzymes and protein-protein interactions, such as those involving hormones and receptors. This method is particularly beneficial when combined with straightforward measurement outcomes, enhancing the learning experience and promoting a deeper understanding of biochemical principles among students.

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Ethical approval

This study (HSEARS20200826002) was approved by the institutional review board of the Hong Kong Polytechnic University.

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