REFLECTIONS ON PRACTICE

Teaching an Interdisciplinary Course on Battery Electric Vehicles Without Disciplinary Prerequisites

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ABSTRACT

Interdisciplinary courses (IDCs) are a new class of courses that form part of the core curriculum of the College of Humanities and Sciences (CHS) at the National University of Singapore (NUS). The course HS2904 "Driving Towards the Future: Battery Electric Vehicles" is an IDC co-taught by the Department of Chemistry and the Department of Economics. Since IDCs have no disciplinary prerequisites, the necessary disciplinary knowledge in chemistry and economics required for HS2904 was taught at the onset of the course within two lecture sessions. This paper reflects on the teaching of essential disciplinary knowledge, how learning of disciplinary knowledge was assessed, and presents some preliminary evidence on the integration of disciplinary knowledge by the students in HS2904.

Keywords: Interdisciplinary courses, pedagogy, co-teaching, team-teaching

INTRODUCTION

One of the aims of the new College of Humanities and Sciences (CHS) at the National University of Singapore is to deliver interdisciplinary learning at scale ("New College of Humanities and Sciences", 2020). The core curriculum, which is compulsory for all undergraduate students in CHS, consists of 13 courses. Of these 13 courses, two are designated Interdisciplinary Courses (IDCs) that can be selected from a basket of courses. The purpose of IDCs is to further develop interdisciplinary learning in students by allowing them to think, synthesise, and integrate knowledge across disciplines. Characteristics that are unique for IDCs include thematic approaches and co-teaching by lecturers from the Faculty of Arts and Social Sciences (FASS) and the Faculty of Science (FoS) for multidisciplinary insights. There are no prerequisites for IDCs.

ADOPTING A THEMATIC APPROACH TO EASE INTEGRATION

Guided by the definition of interdisciplinary as "a knowledge view and curriculum approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem topic or experience" (Jacobs, 1989, p. 8), we proposed and taught an IDC entitled HS2904 "Driving Towards the Future: Battery Electric Vehicles (BEVs)" in Semester 2 of Academic Year (AY) 2022/23. This course covers the **theme** of battery electric vehicles (BEVs) within the larger **context** of electrification of transport with disciplinary perspectives predominantly from chemistry and economics. The course examines the current renaissance of EVs via an integrated approach, incorporating the physics and chemistry of batteries into the environmental, economic, geopolitical, and policy consideration of EVs. This usage of a central theme provides structure and focus to avoid the "Potpourri Problem", where a course becomes "a sampling of knowledge from each discipline" (Jacobs, 1989, p. 2). Knowledge sampling from various disciplines without integration can be seen as a contrast between multidisciplinary and interdisciplinary perspectives (Spelt et al., 2009).

ROLE OF ACADEMIC DISCIPLINES IN INTERDISCIPLINARY UNDERSTANDING

Jacobs (1989, p. 2) states that an effective interdisciplinary programme should have "**both discipline-field-based and interdisciplinary experiences** for students in the curriculum." This is supported by Spelt et al. (2009). Using a systematic review, they found that having the necessary academic disciplinary knowledge is deemed as a subskill that constitutes interdisciplinary thinking. In essence, Boix Mansilla et al. (2000, as cited in Spelt et al., 2009) define **interdisciplinary understanding** as:

> The capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement—such as explaining a phenomenon, solving a problem, or creating a product—in ways that would have been impossible or unlikely through single disciplinary means. (p. 366)

Consequently, without any prerequisites for IDCs, how do we develop interdisciplinary understanding and incorporate discipline-field-based knowledge without alienating or discouraging students who have no prior disciplinary knowledge?[1] In the following sections, we reflect on the teaching of essential disciplinary topics for chemistry and economics in HS2904, what topics/principles were chosen, how learning of the topics was assessed, and how students perceived the teaching of these topics.

IDENTIFYING AND TEACHING ESSENTIAL DISCIPLINARY KNOWLEDGE EARLY

In a broad survey of universities that offer interdisciplinary programmes, Rhoten et al. (2006, p. 11) identify the outcomes expected of students in such programmes, such as critical thinking, problem solving, and analytic skills, as well as disciplinary depth and the ability to integrate diverse knowledge. For HS2904, selected topics were chosen from chemistry and economics so that students can apply and integrate the knowledge acquired to understand topics in BEVs. Since there are no prerequisites for IDCs, essential disciplinary knowledge must be **taught at the onset of the course**. After which, armed with the necessary disciplinary knowledge, students will be able to perform the integration needed for interdisciplinary learning to occur.

TEACHING OF CHEMISTRY AND ECONOMICS IN HS2904

To ensure students start from a common base in chemistry and economics, especially for economics, where a significant proportion of the students did not read economics prior to university, essential topics were taught in these two subjects. As the course only had 11 lecture slots (1.5 hours each) allocated for teaching, the decision was to **allocate one introductory lecture each for essential disciplinary topics in chemistry and economics**.

For chemistry, lithium-ion batteries (commercialised in 1991), with their superior energy density compared to other batteries, are instrumental in the renaissance of EVs. Prior to the lecture on lithium-ion batteries, essential chemistry knowledge to understand this topic was revised in one lecture, such as: **periodicity, chemical equations, redox equations, and basic electrochemistry**. Students were asked to work out examples during the lecture and scientific demonstrations were shown.

For economics, essential concepts such as the **supply and demand model** and **externalities** were taught in the second lecture based on two thematic questions: (a) What factors drive the prices of minerals used in EVs, i.e., **how markets work?** (b) Why is it so challenging to manage the environmental issues related to economic growth and the EV-ecosystem, i.e., **why markets may fail?** Students can assume the role of policymakers, e.g., by allocating property rights, to decide on the mix of public policy approaches to manage the externalities.

The chemistry and economic concepts taught in lectures were revisited during tutorials with about 25 students per group to reinforce and interleave the learning. The chemistry and economics knowledge was tested mid-term as part of HS2904's continuous assessment.

STUDENTS' PERCEPTIONS OF DISCIPLINARY LEARNING

Table 1 depicts students' perceptions of their mastery of chemistry and economics knowledge as measured via matched pre- and post-course Likert scale survey items. The students were surveyed before the first lecture and after the final lecture of HS2094 using a 5-point Likert scale (with 5 being "Strongly Agree" and 1 being "Strongly Disagree"). From the class of 50 students, 25 matched replies were obtained.

Table 1
Pre and post-course perceptions of mastering chemistry and economics concepts in HS2904

Questions	(A+SA)* %	
	pre	post
(CM)** I can find the atomic weight of a particular element from the periodic table.	81	100
(CM) I know the difference between voltage and current.	63	93
(CM) I can write down a balanced chemical equation.	81	96
(CM) I know what a redox reaction is.	85	96
(EC) Each point on the demand curve reflects the highest price consumers are willing and able to pay for that particular unit of good.	64	96
(EC) I know the difference between producer surplus and consumer surplus.	44	92
(EC) I know what positive and negative externalities.	52	88
(EC) I can identify the causes of market failure.	32	80

*A represents "Agree" and SA represents "Strongly Agree".
**CM = Chemistry-related question, EC= Economics-related question.

Table 1 shows the percentage of respondents who agreed and strongly agreed with each item. It can be seen from Table 1 that there is an increase in self-reported disciplinary-specific knowledge and understanding over the semester for both chemistry and economics. Especially noteworthy is the economics items on the causes of market failure ("I can identify the causes of market failure."), where there was a significant increase from 32% positive responses pre-course to 80% post-course. These fundamental economic concepts facilitate the understanding and the integration of technological solutions with policy mix when managing climate change.

In the second component of the post-course survey with Likert scale items, 24 completed responses were obtained. The items related to chemistry/economics fundamentals are given below in Table 2. Students were surveyed using a 5-point Likert scale (with 5 being "Strongly Agree" and 1 being "Strongly Disagree").

Table 2
Post-course items on scientific and social sciences concepts taught in HS2904

Questions	(A + SA)* %
I can follow the scientific concepts taught in the course.	92
I can follow the social sciences concepts taught in the course.	79
After the course, my interest in sciences has increased.	71
After the course, my interest in social sciences has increased.	67
My appreciation of chemistry on the whole has increased after the course.	70
My appreciation of economics on the whole has increased after this course.	71

*A represents "Agree" and SA represents "Strongly Agree".

Table 2 shows the percentage of respondents who agreed and strongly agreed with each item. From Table 2, students self-reported that these disciplinary concepts are accessible, and their interest and appreciation for chemistry and economics have increased.

LECTURERS' REFLECTIONS ON THE TEACHING STRATEGIES

Besides the students, both lecturers also learnt from each other's domain expertise since both lecturers were present in all HS2904 lectures. Hence, they can interleave this knowledge into their own domain-specific lectures. For example, the concept of externalities taught in the introductory lecture for economics was again mentioned by the chemistry lecturer when the environmental impacts of EVs were taught. Similarly, the concept of the S-curve in the diffusion of innovations, mentioned by the chemistry lecturer in his first lecture, is revisited by the economics lecturer when discussing the role of market segmentation and consumer preference at various stages of the adoption cycle, together with the need for policies adjustments. Firth et al. (2021) found that interleaving helps with memory for both the arts and the sciences. Interleaving and revisiting key disciplinary concepts often allows students to achieve greater mastery and integration of disciplinary knowledge.

Furthermore, reading or teaching an interdisciplinary course can facilitate the development of metacognitive awareness and strategies. For example, when teaching the taxonomy of goods: private, public, club, or common resources along the dimensions of rivalry and excludability, the economics lecturer highlights how and why classification is useful in both sciences and social sciences to organise patterns, identify relationships, so as to make a prediction, as done successfully by Mendeleev, who was recognised as the originator of the periodic table and the first to make observable predictions for new elements (Kibler, 2007). The benefit of classification is reiterated using the periodic table when discussing the candidate metals that can be used in a battery. The goal is to move students further along the four levels of the metacognitive learners' framework by Perkins (1992): tacit, aware, strategic, and reflective, by making explicit cognitive strategies such as grouping and classifying, evidence-seeking, and decision-making. In doing so, students transit from domain-specific to generic metacognitive skills, as Veenman and Spaans (2005) observed in their study of first-year and third-year students.

STUDENTS' REFLECTIONS ON INDIVIDUAL DISCIPLINES AND INTEGRATION

At the conclusion of HS2904, as part of continuous assessment, students were asked to submit written reflections on selected topics in HS2904, one being interdisciplinary learning. We found preliminary evidence that the individual disciplinary concepts as taught were manageable (Quote 1) and approachable (Quote 2) to students with little disciplinary background. In addition, the foundational role of individual disciplines in developing an integrated understanding of EVs was evident (Quote 3). For example:

- **Accessibility of chemistry to people with little previous background**
  Quote 1: "Personally, coming from an arts stream background since junior college-with 'O' level combined chemistry and physics being my last contact with the sciences, I was concerned that I would be at a disadvantage as compared to my course mates from the science stream. However, to my surprise I found the course material to be rather manageable as I was able to converse and discuss aspects of the module with my science counterparts."

- **Accessibility of economics to people with little previous background**
  Quote 2: "In fact, I used to think of economics as a terrifying combination of mathematics and essay writing and associated it with old men sitting together behind a TV screen, dissecting everything that is going wrong due to the current policies. This module made economics approachable."

- **Integration of disciplines**
  Quote 3: "This module was not solely about chemistry nor was it about economics. I appreciated how this module was first and foremost about EVs and how specific concepts from the chemistry and economic disciplines can be applied in bolstering my understanding of EVs. That being said, basic concepts—demand and supply, redox reactions, and battery fundamentals—from the two disciplines are absolutely necessary to understand[*sic*] EVs.

  Through this module, I realised that interdisciplinary study is not simply two researchers from different disciplines writing a paper with a section in chemistry and another section in economics. Instead, it is these two researchers analysing the issue together to tease out how one discipline influences the other to form this complex web of interwoven connection."

CONCLUSION

Interdisciplinary Courses (IDCs) in the College of Humanities and Sciences (CHS) have no disciplinary prerequisites. For this course, to ensure common disciplinary background especially in economics where a signification proportion of the students did not have any background, students taking HS2904 were taught essential disciplinary concepts in chemistry and economics in one introductory lecture each by the respective subject lecturer. Pre- and post- course surveys demonstrated that students' perceptions of disciplinary learning *did* occur in both disciplines, with the most gains in economics. Together with the teaching strategies incorporated such as interleaving, students perceive that the disciplinary concepts taught were comprehensible, and their interest and appreciation for both chemistry and economics have increased. From the reflection paper assignment, there was further evidence of accessibility of basic disciplinary concept and its integration in understanding the course topic of battery electric vehicles. Subsequent iterations of HS2904 will continue to incorporate teaching of essential disciplinary concepts and interleaving them in subsequent lectures to strengthen students' integration of these concepts.

ENDNOTE

1. For the inaugural version of HS2904 in the first semester of AY 2022/23, the incoming students were surveyed for their disciplinary background in chemistry and economics. In the class of 50 students, 20% had no A-level (H1 or H2) or IB or polytechnic courses in chemistry; for economics the equivalent percentage is 40%. A-level, IB and polytechnics are the most common education pathways prior to entering tertiary education in Singapore.

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REFERENCES

Firth, J., Rivers, I., & Boyle, J. (2021). A systematic review of interleaving as a concept learning strategy. *Review of Education, 9*(2), 642–684. https://doi.org/10.1002/rev3.3266

Jacobs, H. H. (1989). *Interdisciplinary curriculum: Design and implementation*. Association for Supervision and Curriculum Development.

Kibler, M. R. (2007). From the Mendeleev periodic table to particle physics and back to the periodic table. *Foundations of Chemistry, 9*, 221–234. https://doi.org/10.48550/arXiv.quant-ph/0611287

New College of Humanities and Sciences by NUS delivers interdisciplinary learning at scale. (2020, December 8). Retrieved from https://chs.nus.edu.sg/2020/12/08/new-college-of-humanities-and-sciences-by-nus-delivers-interdisciplinary-learning-at-scale/

Perkins, D. (1992). *Smart Schools: Better thinking and learning for every child*. Free Press.

Rhoten, D., Boix Mansilla, V., Chun, M., & Klein, J. T. (2006). Interdisciplinary education at liberal arts institutions. *Teagle Foundation White Paper, 13*, 2007. Retrieved from https://scholar.harvard.edu/files/boix-mansilla/files/interdisciplinary_education.pdf.

Spelt, E. J., Biemans, H. J., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review, 21*, 365–378. https://doi.org/10.1007/s10648-009-9113-z

Veenman, M. V., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences, 15*(2), 159–176. https://doi.org/10.1016/j.lindif.2004.12.001■