Renovating the Teaching and Learning of << Physical Chemistry >>

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INTRODUCTION

Chemistry is the science of molecules and atoms, of which all matter is composed. It has naturally become established as the central discipline of the natural sciences, and is recognized as the fundamental basis for all the technologies involving our daily life and pressing societal issues, ranging from new medicine to new materials and from energy to environment

"*Physical Chemistry*" is a sub-discipline of chemistry. It is mainly concerned with the application of physics, including its principles, concepts, practices and techniques, in the study of molecules and atoms. While "*Chemistry*" has often been perceived as an empirical discipline based largely on accumulated facts obtained via trial-and-error approaches, it is "*Physical Chemistry*" that has given chemistry its most rational and most quantitative aspect. At the level of undergraduate education, "*Physical Chemistry*" has traditionally been established as one of the core sub-curricula for a chemistry major, and for those programs requiring *Chemistry* as a pre-major such as biological and medical sciences, materials sciences, environmental sciences, and energy sciences. "*Physical Chemistry*" occupies about 30 percent of the total core and required credits for the first degree, Bachelor of Science in Chemistry. The "*Physical Chemistry*" sub-curriculum contains in roughly equal weights both the lecture courses dominated by classroom instructions and the laboratory courses dominated by hands-on experiments.

THE CHALLENGES

"*Physical Chemistry*" has been perceived as the most difficult and the most challenging subject for both teaching and learning in undergraduate Chemistry Programs worldwide [1-

5]. Several causes of this problem have been identified on the basis of experience gained from both teaching and learning. First, "*Physical Chemistry*" [6] by its very nature heavily employs principles, concepts, methodologies and techniques from *Physics*, which in turn heavily utilizes *Mathematical tools*, while students majoring in *Chemistry* or requiring chemistry as a pre-major are normally much less prepared in the latter two subjects. Secondly, the "*Physical Chemistry*" sub-curriculum contains almost equal weights of both lecture courses and laboratory courses for the same set of topics. However, the lack of a proper interface, or the lack of a synergy, between lecture courses and lab courses has made it difficult to achieve the intended learning outcomes for both lecture and lab courses. Thirdly, several key topics in "*Physical Chemistry*", especially those involving "Quantum Theory", are counter-intuitive and run counter to daily experiences. As a consequence, students acquire misconceptions far too often. Fourthly, several important topics in "*Physical Chemistry*" requires their understanding, and therefore teaching, from a "dynamic" or "time-dependent" view instead of a "static" or "resting" view which is often the impression students received from the traditional instruction mode. Fifthly, "*Physical Chemistry*" itself is a vibrant and ever-changing field in terms of the way the research is performed [7] and in its focus. To meet the high-end demand for researchers in physical chemistry and its interfacing and inter-crossing fields, "*Physical Chemistry*" education at undergraduate level must reflect this change in both its syllabus and the way the topics are taught. Last but not the least, "*Physical Chemistry*" is becoming a basic and a required subject for many emerging interdisciplinary programs, including life/medical sciences and biotechnology, materials sciences and nanotechnology, environmental science and relevant technology, and energy science and relevant technology. The current "*Physical Chemistry*" sub-curriculum has not been updated to meet the demands of these emerging interdisciplinary programs.

OUR OBJECTIVES AND APPROACHES

In mid-2006, we started a project in the Department of Chemistry at the Hong Kong University of Science and Technology to develop and implement an integrated and multimedia-enhanced online study station for "*Physical Chemistry*" courses for undergraduate students majoring in Chemistry and for other interdisciplinary programs requiring *Physical Chemistry* in their curricula. The main goal of this project is to tackle the above-mentioned challenges faced in the teaching and learning of "*Physical Chemistry*" at undergraduate level. The specific objectives include (i) to enhance and improve the efficiency of the teaching and learning of "*Physical Chemistry*" courses by integrating the background materials with course syllabi for each topic, by interfacing the lecture courses with lab courses for each topic, and by linking our main syllabus with the international benchmarking syllabus at top universities worldwide, (ii) to update the syllabi, the structure, the teaching/learning modes, and the assessment methods for "*Physical Chemistry*" courses, and (iii) to meet the demand for "*Physical Chemistry*" courses in the new four-year undergraduate programs for both Chemistry major and the new interdisciplinary majors by setting up a set of topic-specific modules.

Currently, we are focusing our efforts on the following five aspects :

(1) *An Online and Multimedia-enhanced Chemistry-Physics-Mathematics Correlation Scheme for Each Topic in Physical Chemistry*: Physical Chemistry consists of many topics such as thermodynamics, kinetics, statistical thermodynamics, quantum theory, atomic and molecular structures, group theory, and spectroscopy among many other more specific topics.

Each of these requires quite different mathematics and physics preparation. To facilitate the teaching and learning of each topic, we are carefully building up an online and multimedia-enhanced topic-specific ‘background’ module that contains the necessary physics and mathematics knowledge for their study. The ‘background’ modules form complete online “appendices” that can be readily cross-referenced in the study of physical chemistry.

(2) *An Online and Multimedia-enhanced Lecture-Laboratory Correlation Scheme*: The physical laws in chemistry are nothing more than the abstractions, quantitative representations, and sometimes logical extrapolations of experimental observations. Therefore, it would be difficult if not impossible for students to grasp the very essences of the topics in “*Physical Chemistry*” without doing both lecture courses and lab courses in a coherent and synergetic manner. In our current curriculum, there is a gap or a lack of synergy between lecture courses and lab courses. We are carefully building up a set of online modules that “correlate” lecture-content with lab-content, so that the knowledge from lectures and experiments can be readily cross-referenced.

(3) *An Online and Multimedia-enhanced Scheme for Topical Modules Tailor-made for Emerging Inter-disciplinary Programs*: Physical Chemistry is a required basic subject for several emerging inter-disciplinary UG programs , including “Bio-”, “Nano-”, “Enviro-”, “Energy” programs. The current “*Physical Chemistry*” sub-curriculum is not well-suited to these new interdisciplinary programs. To meet the need of these new programs, we are developing a set of module-based, topic-enhanced online study aids that include correlated topics from chemistry, math and physics.

(4) *An Online Cross-Reference Scheme*. We are working on a quick and easy-to-use online cross-reference guide for accessing the most relevant and most updated books, articles and internet resources for each concept, topic and subject in *Physical Chemistry*, as well as for accessing syllabi of similar courses from top universities in the USA and UK. This function is aimed at constantly matching the quality of our curriculum and the standard of our student’s study to the best in the world. Concept maps are also being established in each subject to facilitate students’ learning and understanding.

(5) *Establishment of “Intended-Learning-Outcomes” and “Assessment Criteria” for every topic in Physical Chemistry, and for “Physical Chemistry” as a whole integrated sub-curriculum, and the development of “Assessment Methods” that are consistent with the established “Intended-Learning-Outcomes” and “Assessment Criteria”.*

We will demonstrate some of the features already established in the current version of the Study Platform.

ACKNOWLEDGEMENTS

This project is supported by CLI project 00399S and by the Department of Chemistry, the Hong Kong University of Science and Technology. We thank Professors Yi-Jing YAN, Shi-He YANG and Dr. Yu-Fong YEN for helpful discussions.

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[2] See for example, *Resources for Chemistry Educators*, International Union for Pure and Applied Chemistry (IUPAC) (http://www.chem1.com/chemed/).

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