A Model of Interdisciplinary Curricular Collaboration: Inquiry Based Real-World Case Studies for Introductory Bioinformatics and Computer Science Courses

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Abstract – *An interdisciplinary team of computer science and biology faculty is developing inquiry based real-world case studies for introductory bioinformatics and computer science courses. The collaboration was designed to provide a model of such work and explore its challenges, benefits and potential. The step-by-step process of curricular development is analyzed. It included the selection of a real-world science problem, the integration of the project into existing curriculum and the creation of a wide range of corresponding learning activities. Combining scientific inquiry, service learning and computer science tools and methodology is a promising pathway for bringing undergraduate science, technology, engineering and mathematics (STEM) education into the twenty first century. The guidelines for future partnerships are discussed.*

Keywords: interdisciplinary curriculum, bioinformatics, real-world problems.

1 Introduction

Interdisciplinary inquiry based projects have become the latest frontier in STEM undergraduate education [1]. However, they need to represent more than the sum of the individual STEM fields [2]. Integration of diverse subjects in the real-world setting creates a challenge for faculty whose expertise is limited to a specific discipline. In undergraduate courses, it requires a productive collaboration of instructors from different departments and schools, which is often lacking. Particularly important is the dialogue between specialists in computer science and natural sciences (biology, chemistry and physics). This partnership is becoming critical in STEM research as evidenced by the growing role of bioinformatics and computational biology, physics and chemistry. At the same time, undergraduate STEM education curricula are often lagging behind in adopting the changes. Although there are instances where the collaboration of instructors from different disciplines has produced effective curricular modules, institutional barriers and differences in training, experience and professional cultures often have a limiting effect. To optimize the effectiveness of these interdisciplinary collaborations and the curricular products they produce, we conducted a case study of interdisciplinary curricular development that was supported by NSF CPATH and NSF I^3 awards at New York City College of Technology. Faculty from Computer Systems Technology (CST) and Biological Sciences Departments developed curricular units that could be utilized in introductory bioinformatics and computer science courses. The goal of the study was to explore the challenges of interdisciplinary curricular collaboration and provide the guidelines for future partnerships. The pedagogical goal was to introduce real-world inquiry based interdisciplinary class projects into introductory STEM courses in order to engage students in active learning and problem solving. The learning activities aim to give students a taste of actual field projects as they are developed in industry based on the computer system analysis and project management methodology [3, 4].

2 Project design process

2.1 Selecting a real-world STEM problem

The real-world inquiry based projects that integrate computer science and biology may address a variety of current STEM research problems and use a number of applications. As we discussed the options, the following criteria for selection were considered.

1. Will the project allow the students to relate to the problem on the personal level? Are there familiar themes and experiences providing additional motivation for the learning activities and engaging student imagination, sense of service to the community and scientific curiosity?
2. Are there fundamental biology and computer science topics that could be taught based on the project? How do these topics fit into the course curriculum? How can the traditional teaching of the subject support the project and vice versa?
3. Does the level of the required learning activities correspond to the introductory STEM course? How will the project complement the course instruction? Will every student in the class benefit from the project?

Among the potential choices in biology were the following: development of a new drug in the pharmaceutical industry, research of a particular genetic disease and epidemiological study of an infection outbreak. All three satisfied the first criterion but elicited various considerations in regard to the second and the third. After extensive discussion, it was decided that a particular genetic disease study will provide the optimal balance of the appropriate level of complexity and the wide range of topics required in the introductory bioinformatics course. The choice of the genetic condition was *sickle cell disease*. It is a well-known affliction that combines a diverse background in molecular biology and genetics, a dramatic history of advanced research and a number of unresolved medical problems [5, 6]. Addressing some of these problems is the dual task of bioinformatics and computer science. The need for databases, computer tools and online applications in these combined fields is great and presents an excellent opportunity for the real-world projects.

2.2 Integrating the project into existing curriculum

The curricular components used in the case study were extracted from three courses: Elements of Bioinformatics, BIO 3350, Systems Analysis and Design, CST 2406, and Computer Information Systems Project Management, CST 4800. The project instructional materials could be modified for implementation in any of these courses, at the appropriate level of detail. The contributions of these curricula complement each other. Bioinformatics provides scientific framework for addressing real-world biological and medical problems. It is based on the modern knowledge of molecular biology, particularly on understanding of DNA sequence, gene expression and protein sequence, structure and function. The framework includes using resources and methods of computer science and information technology – computer algorithms, databases, search tools and sequence alignment tools, among others. *Sickle cell disease* provides an excellent model of a genetic condition. It is caused by a substitution mutation in a single gene coding for a major protein in the red blood cells – hemoglobin. One letter «misspelling» in the gene's DNA sequence leads to alterations in the protein sequence, structure and function. This, in turn, causes sickling of the red blood cell and a multiplicity of signs and symptoms. Although the pathogenesis of the disease is well understood, the treatment options are limited and the condition may be fatal. Partial immunity to malaria in carriers explains high prevalence of the disease in the tropical countries. Potential topics for discussions include population genetics, poor choices for disease prevention (family counseling and planning), search for better treatments and the prospects for finding the cure.

The curricula of two computer courses, Systems Analysis and Project Management, contribute general methodologies for the development of information systems and for executing the phases of the project – the sequence of steps and milestones, the format of documents and products designed in the process of development of an information system or computer application for real-world problem solving. The students in the Bioinformatics course will benefit from this systematic approach, which is often omitted in the bioinformatics curriculum. It can be considered as the scenario of the professional internship: this is how computer science specialists create and manage information systems in response to user requests. This is a central feature of the case study that makes it applicable to other STEM courses and projects. The methodologies will remain, but specific bioinformatics-related tasks will be substituted by other discipline related tasks. The students in the two computer courses will benefit from working on a science oriented project which brings a new prospective to the course – excitement of scientific discovery, urgency and humanitarian significance of medical research, the potential benefits to the effected population. The project is done over the course of the semester, in parallel with regular topics, which complement the activities. In the Bioinformatics course, the greater emphasis is on the scientific background and subject specific tools. In Systems Analysis course, it is on the process and products. To formalize this «cross-pollination» process and structure the curricular integration and its assessment, the following guiding questions were proposed.

1. What are the curricular contributions of each field to the project? Are there synergies between them that add value and bring the conversation in the classroom to a higher level?
2. What are the benefits of the project to students in each course? What kind of new prospective, knowledge and skills does it bring to the students?
3. What are the time demands of the project activities vs. existing curriculum? What is the optimal time line and time management for the project over the course of the semester?

2.3 Designing learning activities

The answers to the questions about time allotment require considering project design and learning activities in greater detail. However, an inquiry based case study does not start with clearly defined instructions that predetermine all student actions. It begins with a scenario or question that requires active involvement of students in designing the potential solutions [7]. This approach driven by project management methodology may be suggested for a number of STEM disciplines. Its general value is in providing a framework for interdisciplinary collaboration that can be applied in a variety of the curricular development case studies. In the context of the sickle cell disease research that served as a unifying theme for all the learning activities in this particular case study, the following scenarios were suggested.

1. Understanding data required for researching various aspects of a particular biomedical problem. Choosing a problem, e.g. researching genetic variants of the gene associated with the sickle cell disease and gene expression patterns, and planning to develop a

database. Participants: students of the bioinformatics class.

2. Defining the scope of work for the database development for the chosen problem, e.g. sickle cell disease protein sequence, structure and function in relationships with the gene expression patterns in different patients. Participants: students of the bioinformatics and computer science classes.
3. Defining and refining system requirements for the repository of gene variants and gene expression data in sickle cell disease patients. Participants: students of the bioinformatics and computer science classes.
4. Modeling system requirements for the repository of gene variants and gene expression data in sickle cell disease patients. Participants: students of the computer science and bioinformatics classes.
5. Designing and developing a simple database [8, 9] for the repository of gene variants and gene expression data in one of the available software/tools (MS Access, MySQL or commercial database management systems). Participants: students of the computer science classes with the assistance of the bioinformatics students.
6. Populating the database with data and executing simple queries that may illustrate and define the benefits of the database for research of the problem. Participants: students of the computer science and bioinformatics classes.
7. The project can be continued in subsequent interdisciplinary courses, e.g., elective project based courses in computer science and other STEM disciplines.
    a. Developing a basic web application for the online sickle cell disease research database (with computer science students).
    b. Developing a set of analytics to process data from the sickle cell disease research database in order to analyze the trends and tendencies identified in the data (with applied mathematics students).

The projects and activities may be rotated in different classes and semesters. All of them will require a general introduction to the sickle cell disease, its biological background and societal implications. Systems analysis introduction will include case background, organization structure, information systems facilities and problem description. Better understanding of the systems analysis process and stages help streamline and guide the steps of the STEM problem solving in the classroom, as it does in the real world scientific exploration and discovery. These phases include scope definition, problem analysis, requirements analysis, logical design and decision analysis [3]. The projects based on designing particular tools (databases, web servers) will require more technical skills and can be assigned to more advanced and experienced students. Other projects involve systems analysis without designing the actual system. They can be successfully implemented by all students working in small groups over the period of a few weeks. In Bioinformatics, the major topics of the course (DNA sequence analysis, protein sequence, structure and function, gene expression analysis) are illustrated and reinforced by the *sickle cell disease* case study. The projects are completed and summarized in group presentations to the class by the end of the semester.

3 Challenges, benefits and the potential of the interdisciplinary collaboration in undergraduate computer science and other STEM courses

When faculty from different departments and schools (School of Technology and Design and School of Arts and Sciences) start collaborating on the interdisciplinary curricular STEM projects, the typical initial challenge is not knowing well enough what the other is doing, both in the classroom and professionally, in industry and research. This mimics the initial situation between computer science specialists and users in multiple fields. It is necessary to overcome this obstacle by learning from each other and from the literature, and the earlier it is done, the more productive the collaboration becomes. In our experience, participation of the external partner from the Polytechnic Institute of New York University provided an additional impulse in the beginning of the project. As the Director of the Bioinformatics program, he had both the academic and the industry perspective, and helped to launch the conversation. Exchanging curricular materials and discussing them regularly in informal meetings were essential. The benefits of learning the principles, the language, the goals and the techniques of the partnering discipline extend beyond one project. This understanding will inform one’s teaching and add new aspects to the instructor’s view of science and technology. The next challenge was to make the optimal selection of the real-world STEM problem for the case study. Here, the necessary step is looking at the problems from the students’ point of view. It is important to select an exciting challenge that combines the potential for scientific inquiry at the appropriate level, ideas of service learning and the necessity of using computer science tools and methodology. Although we do not include service to the community as a project requirement, the premise of helping people in need is an important motivational component that can be emphasized, implicitly or explicitly, in a variety of ways [10]. The scientific inquiry and computer science components should be tailored to the student academic level. In this respect, expecting too much or too little from the students may cause unanticipated problems and interfere with the project progress. The benefits of good problem selection are significant, both in motivating the students and in allowing them to achieve success in active learning. Integrating the project into the existing curriculum creates two basic challenges. One is the correspondence between the project and the fundamental topics of the course. In the case study, the project does not replace the topics but complements and reinforces them. Another challenge is the time constraints that any existing course curriculum imposes. Introducing a new project or learning activity requires additional time – both instructional time in class and individual and group work time either in class, at home or at some other facility. Balancing it and improving student productivity is the key to success. It provides the students with new perspective, additional skills and a more meaningful learning experience. Finally, learning activities of the case study, in addition to being highly technical, need to engage students' imagination in the context of the real-world professional situation. There are two basic roles they can play in these scenarios: one is computer science specialists developing the computer system and another is product users or clients, e.g. biologists, medical doctors or biotech researchers [11]. In our classes, the first role most likely belongs to the computer science and applied mathematics majors and the second – to the majors in other science and technology programs. The level of student engagement in the activities depends on many factors including clarity of introduction, optimal level of assignment difficulty and fair assessment, among others. The assignments are not limited to the ones proposed above. These are just a few examples that could be implemented and continuously modified and improved based on the feedback from the students. An interdisciplinary collaboration in undergraduate computer science and other STEM courses has the great potential for new curricular module development, primarily because of the interdisciplinary nature of modern science and technology, and it is likely to proceed along the lines of the proposed model.

4 Conclusions

This case study applied a systematic approach to exploring challenges and benefits of the interdisciplinary curricular collaborations in computer science and other STEM courses. Among the conclusions was the realization that, in spite of considerable difficulties, especially in the initial stage of the study, such collaboration is possible and even vital for the future of the undergraduate STEM education. The project worked on two levels. First, it was beneficial for faculty from different departments and schools to initiate a productive conversation about the interdisciplinary curriculum. This faculty professional development case study may serve as a model of collaboration that can be easily adapted in other disciplines. The step-by-step approach, the guiding questions and criteria and the guidelines for future partnerships provide the framework for future curricular work. Second, the proposed modules provide an opportunity for the students in computer science and bioinformatics courses to engage in interdisciplinary collaboration which is typical for modern science and technology, both in industry and in research. At City Tech, a series of similar case studies has been in development including faculty collaborations between the Electrical Engineering and Physics Departments and between the Architectural Technology and Mathematics Departments. Administrative support and encouragement of these initiatives appear to be a critical component of success.

5 Acknowledgements

The work reported in this paper was partially funded by the National Science Foundation, NSF CPATH award # 0939120 and NSF I^3award # 0930242. Prof. Kalle Levon, Director of the Bioinformatics program at the Polytechnic Institute of New York University, contributed to the discussion of the project design.

6 References

[1] Maria A. Ruiz-Primo, Derek Briggs, Heidi Iverson, Robert Talbot and Lorrie A. Shepard. "Impact of Undergraduate Science Course Innovations on Learning"; Science (AAAS), Vol. 331, 1269-1270, March 2011.

[2] David J. Asai. "Measuring Student Development"; Science (AAAS), Vol. 332, 895, May 2011.

[3] Jeffrey Whitten and Lonnie Bentley. "Introduction to Systems Analysis and Design" McGraw Hill Publishing Company, 2006.

[4] Kathy Schwalbe. "Information Technology Project Management". Course Technology Publishing Company, 2009.

[5] Jonathan Pevsner. "Bioinformatics and Functional Genomics". John Wiley & Sons Publishing Company, 2009.

[6] Betty S. Pace. "Renaissance of Sickle Cell Disease Research in the Genome Era". World Scientific Publishing Company, 2007.

[7] Bruce Albert. "A New College *Science* Prize"; Science (AAAS), Vol. 331, 10, Jan. 2011.

[8] Graeme Simsion, Graham Witt and Morgan Kaufmann. "Data Modeling Essentials". Morgan Kaufmann Publishing Company, 2004.

[9] Len Sinverston and Paul Agnew. "The Data Model Resource Book, Vol. 3: Universal Patterns for Data Modeling", Wiley Publishing Company, 2009.

[10] Robert G. Bringle and Julie A. Hatcher. "Implementing Service Learning in Higher Education", The Journal of Higher Education, Vol. 67, No. 2, 221-239, Mar. 1996.

[11] Bryan Bergeron. "Bioinformatics Computing". Prentice Hall Publishing Company, 2003.