An innovative interdisciplinary curriculum in financial computing for the financial services industry

A. Joseph & D. Anderson
Pace University, USA

Abstract

Finance is a fast growing field in business and is among the fastest growing in scientific computing, helping to sustain economies that include those of New York City and of the United States. The dynamics of finance have enticed computer scientists, engineers, mathematicians, and physicists. This has helped in the growth of interdisciplinary fields that involve computational finance, financial computing, financial engineering, mathematical finance, and quantitative finance. While most of these interdisciplinary programs are introduced to graduate students at universities, few of them are introduced to the undergraduate students. The frequent model that includes a computer science minor and a financial major requires a finance student to be in a general computer science minor that is open to all students who satisfy the minimum requirements for the minor. This interdisciplinary model does not serve sufficiently the needs of industry and of society. The study introduces an interdisciplinary major/minor curriculum model that seamlessly integrates computer science into finance through free elective credits. The model is that of financial computing that is both discipline and industry oriented in the university. The paper of the study evaluates the financial computing model, indicating how it conforms to the needs of financial firms in industry and of society and that of the international Basel II Capital Accord. This study will benefit educators and researchers in integrating a special and timely curriculum model helpful to the financial services industry.
Keywords: assessment, curriculum models, disciplinary grounding, finance, financial computing and interdisciplinary curriculum.

WIT Transactions on Modelling and Simulation, Vol 43,
www.witpress.com, ISSN 1743-355X (on-line)
doi:10.2495/CF060061

1 Background

At the core of information technology is computer science, which has transformed an industrial society to an information society, with a knowledge-based economy where information is a commodity and its efficient processing by a financial firm can lead to a competitive advantage. Its impact is likely to affect finance and economics immeasurably (Tsang and Serafin [1]). The financial services industry was one of the first in the civilian sector of the global economy to computerize business. Financial institutions, such as Bear Stearns in the United States, prefer to recruit graduates of computer science, finance, accounting, or some related disciplines. Finance is likely the fastest growing field in business and is among the fastest growing areas in scientific computing (Haugh and Lo [2]). The dynamic nature of finance and the challenging problems inherent within it have attracted many professionals, including computer scientists, engineers, mathematicians, and physicists [1, 2, 10]. This attraction to modern finance has resulted in the growth of many vibrant and related interdisciplinary fields that involve finance. Examples include computational finance, econophysics, financial computing, financial engineering, mathematical finance, and quantitative finance. While most of these interdisciplinary programs are offered at the graduate level, a small but increasing number are offered at the baccalaureate level. Study identified less than 20 such programs internationally.

Bransford et al. [3] reported three major findings about learning that are based on research and "that can beneficially be incorporated into practice."

1. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test, but revert to their preconceptions outside the classroom.
2. To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in…a contextual framework, and (c) organize knowledge in [methods] that facilitate retrieval and application.
3. A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.

They further emphasized that learning transfer from one context to another is critical to understanding and that ultimately the learner needs to be able to transfer learning from the academic setting to the "[daily] setting of home, community, and the [office]." They suggested that schools need to become collaborative and teamwork oriented, rely on tools for problem solving, and promote contextualized reasoning conditioned on abstract logic. Moreover, they outlined that learning transfer is influenced by the following factors: degree of mastery of the original subject, context, relationships between the learnt and tested material, learners' active involvement in the learning process, frequent and timely performance feedback, learners' self-awareness of their level of learning and assessment of it, ability to build on previous knowledge, ability to understand conceptual change, and cultural practices. Mathison and Freeman [4] reported that the main goal of the many recent developments in interdisciplinary learning is aimed at helping students attain a sufficiently deep understanding of the concepts, so that they can make the necessary connections to their daily lives. They further referenced research that found "forming connections between fields of knowledge is an essential educational need for success in the 21st century". This view is also supported by Mansilla [6].

Interdisciplinarity is not a clearly defined concept. This is evidenced in the Different definitions furnished by researchers [4–6, 8, 14, 15]. Some of these definitions assume names that depend on the level and the method that two or more disciplines are combined. They include crossdisciplinary, multidisciplinary, pluridisciplinary, transdisciplinary, metadisciplinary, integrated, and integrative [4, 5, 14]. Nissani [5], who indicated interdisciplinarity as a multidimensional fluid continuum, furnished the following practical definition: "bringing together in some fashion distinctive components of two or more disciplines." To support his definition, he outlined four types of interdisciplinarity: knowledge, research, education, and theory. He further stated that:

> At any given historical point, the interdisciplinary richness of any two exemplars of knowledge, research, and education can be compared by weighing four variables: the number of disciplines involved, the distance between them, the novelty and creativity involved in combining the disciplinary elements, and the degree of integration.

He expounded on degree of integration by saying that meaningful "integration must satisfy the condition of coherence: the blending of elements is not random, but helps to endow knowledge, research, or instruction with meaningful connections and greater unity." However, he acknowledged that the ranking of interdisciplinary richness is not a measure of quality. Mansilla [6] addressed the issue of quality in an interdisciplinary learning environment, through interdisciplinary understanding and informed assessment of students' performance. She defined interdisciplinary understanding as follows: "the capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement." Examples of cognitive advancement include creative problem solving and product creation using the knowledge and skills from more than one discipline. Within this definition, the disciplines maintained their distinctive features and their interaction at the boundaries are leveraged to obtain the desired solution. The four main premises supporting this definition of interdisciplinary understanding are the following: performance – accurately and flexibly applying learnt concepts to novel situations; disciplinary grounding – being deeply informed by disciplinary expertise; integration and leverage – blending disciplinary views; and purposefulness. Mansilla [6] further provided the framework for assessing a student's performance that is consistent with her definition of interdisciplinary understanding. The assessment criteria included disciplinary grounding; integrative leverage; and a critical stance where there is clarity of purpose, reflectivity, and self-critique. Quality interdisciplinary student work must be able to withstand critique when it is evaluated "against its goals." Ivanitskaya et al. [7] indicated that "repeated exposure to interdisciplinary thought [helps] learners to develop more advanced epistemological beliefs, enhanced critical thinking ability and metacognitive skills, and an understanding of the relations among perspectives in different disciplines." Bradbeer [8] said that interdisciplinary study is not easy to achieve because of the problems of functioning in different disciplines and synthesizing disciplines. He indicated that these problems resulted from differences in disciplinary epistemologies, discourses, and traditions of teaching and learning, as well as differences in students' learning styles and techniques. He indicated that helping students to become self-aware active learners was a critical step in enabling them to function across and within different disciplines. Furthermore, he indicated that disciplinary epistemologies, discourses, and traditions of teaching and learning were supportive evidence of disciplines being structures of both knowledge and cultures. He noted that although knowledge construction in a discipline may be unique, learning the knowledge is not: epistemology and culture are separable issues in teaching. Bradbeer [8] indicated that students' learning styles was a factor in their choice of a discipline. However, his investigations of Kolb on learning style and forms of knowledge, and his investigation of research on the Myers Briggs personality types, indicated the possibility of students successfully studying academic disciplines that do not necessarily match their preferred attributes. He further noted that teachers' concepts and practices of teaching and learning are also a hindrance to interdisciplinary learning in higher education. Bradbeer [8] noted research implying that most teachers' idea of teaching is information transfer. This mode of teaching does not promote deep learning.

From research of undergraduate interdisciplinary curricula that combine computer science and finance, the study introduces three basic models: university wide, discipline oriented, and industry oriented. The university wide model involves the finance major taking a computer science minor open to all students in the university. The discipline oriented model may use the major/minor principle of the university wide model with the minor specifically designed to meet the needs of the finance major. The industry oriented model integrates finance with computer science to meet the financial industry need for new graduates. The university wide model is the most common.

Study introduces an interdisciplinary major/minor curriculum model that seamlessly integrates computer science into finance through its free elective credits. It is called financial computing. This model is both discipline and industry oriented. This curriculum is unique and innovative: its capstone course purposefully, theoretically, and experientially integrates finance and computer science where students perform "real world" financial problem solutions under the mentorship of industry experts and entrepreneurs. Study contrasts this model with the existing ones and indicates how it meets the needs of students, industry, and society.

2 Introduction

Education's major economic roles include the public good of knowledge production and the private good of status enhancement (Appold [9]). These two roles "coincide when the skills taught are needed for the performance of tasks…and easily measurable". Objective in the financial computing curriculum is to satisfy the needs of the student and the public. It is expected that there will be challenges. These may include students' engagement in surface learning and faculty preference for information transfer as their main mode of teaching. Teachers will be encouraged to use teaching techniques, procedures, and examinations that promote active and reflective learning to furnish students with tools for recognizing and interpreting concepts within and between disciplinary frameworks. Teachers will also be encouraged to reflect on their teaching, challenge students' learning styles, and help students become self-aware learners. This should facilitate both intradisciplinary and interdisciplinary learning and promote an efficient learning process. This efficiency will make students more functional in the knowledge-based economy, where they can easily access, manipulate, and interpret units of knowledge (or data) in a novel manner and within different contexts so as to generate greater understanding or new knowledge.

The central objective of integrating finance with computer science is to improve the learning of finance students in the context of computing to meet the needs of the student and the public. Many of the problems in modern finance are currently being tackled using the tools of scientific computing as found in physics, engineering, mathematics, and computer science. Some of these problems include the dynamic portfolio optimization problem (Haugh and Lo [2]) and risk management for large portfolios. At the same time, some of the basic concepts in economics with implications in finance are being re-examined using very large financial datasets, advanced algorithms, complex models, and the processing power of computers (Tsang and Serafin [1]). Two examples are rationality and the efficient market hypothesis. The financial industry needs employees with a good foundation in mathematics and computer science and a "strong interest in finance and financial markets" for positions in quantitative modelling and analysis, risk management, and portfolio management (IAFE [10]). Moreover, with the Basel II Capital Accord scheduled for implementation within the next two years (Basel Committee on Banking Supervision [11]), it is anticipated that there will be an increased demand for technically trained graduates with finance backgrounds, especially in the areas of risk management and quantitative modelling. This accord is likely to have a special impact on New York City, the nation's financial center and the central location of Pace University.

Although there is a demand in the financial industry for technically trained finance graduates with strong mathematical and computing skills, the typical finance graduate is inexperienced in computer programming languages, such as C/C++ and Java. In the financial computing curriculum introduced in this study, finance students will learn to program in Java, thereby developing their programming skills. In addition, they will develop their analytical, quantitative, interpersonal, collaborative, communication, and critical thinking skills as well as an entrepreneurial mindset. The computer science component of the financial computing option of finance will be a 13-credit minor. In fact, students will take eight credits of programming, four credits of data structures and algorithms, and four credits of financial computing. Therefore, the financial computing program will deliver graduates who are likely to help the New York City financial community meet its challenges by hiring local technically trained finance graduates.

3 Curriculum design methodology

Study discloses three basic models of undergraduate computer science and finance integration. They are called the university wide model, the discipline oriented model, and the industry oriented model. The university wide model combines the finance major with a computer science minor where the computer science minor is generic, open to all students within the university that meet its minimum requirements, and tends to favour students with strong mathematical or engineering background. This model may serve the needs of the student, but it does not necessarily serve the needs of industry and the rest of the public. Examples of this model can be found at New York University, Stevens Institute of Technology, and Duke University. The discipline oriented model may or may not use the major/minor principle of the university wide model. If a computer science minor is used by a university, it is specifically designed to meet the needs of the finance major or a group of majors that include finance. Otherwise, the computer science courses are seamlessly integrated into the finance or hybrid finance curriculum. An example of this model is found at Western Michigan University, where finance students take the general computer science minor tailored to non-science students. Most examples of the discipline oriented model are of the integrated nature – integrating mathematics with finance and leveraging it with computer science. These programs tend to target students with strong quantitative skills and adequate computer programming capabilities. Rice University's computational finance minor and University of Michigan's mathematics of finance and risk management are examples. The industry oriented model purposefully integrates finance with computer science usually in a single curriculum without a minor component, and it targets the need in the financial industry for graduates with strong quantitative and computing skills as well as very good business related skills. Three examples of this model can be found in the financial computing curricula at Northwest Missouri State University and Brunel University, as well as in the computational/quantitative finance program at the National University of Singapore. The university wide model is the most common while the discipline oriented is the least because it is an emerging model. A problem with the major/minor component of the university wide and the discipline oriented models is that they do not necessarily simultaneously satisfy the needs of the student and the public. In the university wide model, it is difficult to achieve cognitive advancement, because the disciplines are combined in a simplistic sense – they are set side by side and usually with no attempt made to assess for interdisciplinary understanding. On the other hand, the industry oriented model may serve the need of the public, but it does not necessarily serve the need of the student, since the student may only be motivated by external forces to respond to public demand.

Our university's original bachelor of business administration (BBA) degree program, with a major in finance and minor in computer science, is an example of the university wide model. It consisted of 60 university core credits, 33 business core credits, 16 finance credits, 17 or more computer science credits, and 6 credits of auxiliary economics courses. The 13 free electives in the finance program were subsumed in the 17 computer science credits, which were generic university wide computer science minor courses. Since the finance program was 128 credits without the computer science minor and at least 132 credits with it, and the computer science minor was generic – open to the university wide population, there was a disincentive for finance majors to take the computer science minor. The proposed curriculum option is a redesign of the original one, because it replaces eight credits of computer science courses that have additional prerequisite requirements with a 4-credit project based financial computing course. Moreover, it reduces the computer science minor to 13 credits, which is the same as the number of free electives, indicated in Figure 1. Therefore, the finance degree program now becomes 128 credits, with or without the computer science minor. This updated computer science minor for finance majors constitutes a financial computing option of the finance degree program. It consists of courses in high level programming languages, such as Java, data structures and algorithms, and financial computing. These courses will provide the finance major practitioner-level skills in the four functional areas of computer science: algorithmic thinking, representation, programming, and design (Denning [12]).

The financial computing course will be the capstone course for the minor; its objectives include the following:

1. Students will acquire a fundamental understanding of the key scientific concepts and mathematical tools used in modern finance to develop and implement financial models that describe financial situations.
2. Students will gain practical understanding of planning, designing, and developing reasonably scaled financial software products.
3. Students will understand the role of creative thinking and innovation in new business creation, gain experience in business plan development, and acquire tools needed for an entrepreneurial mindset.
4. Through participation in software project development teams, students will develop team-building, social, and organizational skills that they can further develop in other classes and in their professional careers.

The course's main components are computing, finance, and experiential entrepreneurship.

It will use financial and business experts, computing professionals, and entrepreneurs to mentor and guide students in their project choice and project development. In financial computing, students will leverage their knowledge and

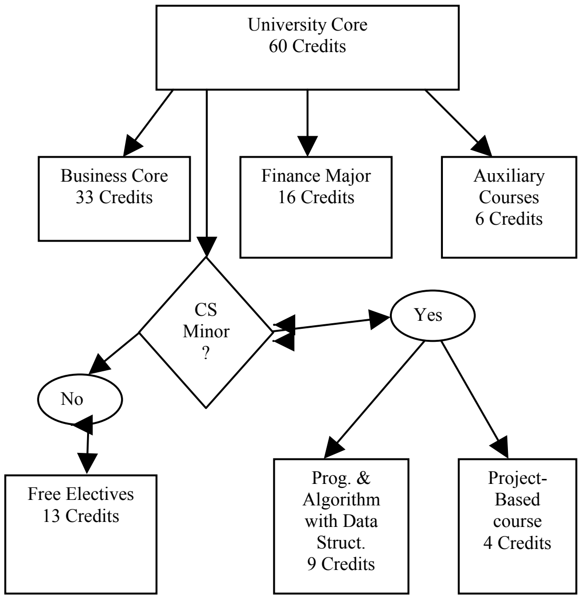

Figure 1: 128-credit finance major with computer science minor.

skills of finance, computer science, and experiential entrepreneurship to develop a creative and innovative financial software product. Students will receive frequent and timely feedback on their performance and progress. The courses in the financial computing option will be taught using a combination of lecture, discussion, cooperative/collaborative learning, problem solving, and project and laboratory instruction, in order to actively involve students' in knowledge generation and skill development. Faculty shall train students in teamwork skills, while leveraging their learning styles to improve understanding and furnish students with the tools to become reflective learners. The assessment of the computer science courses will include written and oral examinations, peer evaluations, portfolios, journals, project demonstration and evaluations, computer program evaluation, project documentation, and project reports. These assessments should illustrate that the students have attained an interdisciplinary understanding: show disciplinary grounding in finance, computer science, and experiential entrepreneurship; show integration of these three disciplines and their use to the advantage of each other; and show knowledge of the capabilities, limitations, and implications of their projects.

4 Implications

Today's employers need employees who are business minded and computer literate. IAFE [10] reported that a growing number of financial firms have recognized that computing and mathematical skills are essential for business success, and therefore increased their recruitment of students with financial computing related degrees. In a 2001 National Association of Colleges and Employers survey to determine the qualities employers seek most in applicants, the leading ones cited were written and oral communication, honesty/integrity, teamwork skills, interpersonal skills, motivation/initiative, strong work ethic, analytical skills, flexibility/adaptability, computer skills, and self-confidence (Joint Task Force of Computing Curricula [13]). Moreover, leading financial institutions, such as JPMorgan Chase and Bear Stearns, prefer entrepreneurial recruits with strong analytical, quantitative, and communication skills. In today's financial business environment, computing technology support systems are needed to manipulate and process huge volumes of data and to effectively simulate financial situations.

In the proposed curriculum students will integrate financial theory and principles and computing and mathematical science theories and techniques with their knowledge of experiential entrepreneurship and financial products to design and develop creative and innovative financial products for a targeted sector of the financial industry. The knowledge, skills, and mindset developed in this curriculum are those needed to develop and grow in today's financial and supporting information technology systems firms. In addition, the curriculum will prepare finance students for graduate studies in financial computing, where most other students' undergraduate background is in computer science, physics, mathematics, and engineering (IAFE [10]). Furthermore, interdisciplinary major minor curriculum mode of this study integrates computer science with finance into a financial computing curriculum that combines elements of the discipline and industry oriented models.

This integration furnishes the finance major/computer science minor curriculum with a unique characteristic among curriculum models: its capstone course, financial computing, purposefully, theoretically, and experientially integrates finance with computer science and leverages the synthesis with experiential entrepreneurship to obtain an industry orientation. Thus, the model is designed to enable students to achieve cognitive advancement at the boundaries of finance and computer science and maintains its academic focus through its discipline orientation.

5 Conclusion

The financial computing curriculum of the study is likely to offer finance students an excellent foundation in interdisciplinary thinking and understanding; a strong foundation in programming, basic principles of software engineering, and the fundamentals of data structures and algorithms; and solid grounding in teamwork, collaboration, social, and communication skills. It offers these students privileged knowledge in experiential entrepreneurship from industry experts. Thus, the proposed financial computing curriculum model of this study is likely to furnish entrepreneurial graduates who are able to help the New York City financial community meet its impending demand for strong computing, quantitative, analytical, and teamwork skills.

References

[1] Tsang, E. & Serafin, M., Computational finance. *IEEE Computational Intelligence Society*, August, pp. 8-13, 2004.

[2] Challenges in Financial Computing; Haugh, M. & Lo, A. http://web.mit.edu/alo/www/Papers/haugh2.pdf.

[3] Bransford, J., Brown, A., & Cocking, R., (eds). *How People Learn: Brain, Mind, Experience, and School*, National Academies Press: Washington, D.C., pp. 3-66, 1999.

[4] The Logic of Interdisciplinary Studies; Mathison, S. & Freeman, M., ERIC Document Reproduction Service No. ED418434. http://www.eric.edu.gov/.

[5] Nissani, M., Fruits, salads, and smoothies: a working definition of interdisciplinarity. *Journal of Educational Thought*, 29(3), pp. 121-128, 1995.

[6] Mansilla, V., Assessing student work at disciplinary crossroads. *Change*, January/February, pp. 14-21, 2000.

[7] Invanitskaya, L., Clark, D., Montgomery, G., & Primeau, R., Interdisciplinary learning: process and outcomes. *Innovative Higher Education*, 27(2), pp. 95-111, 2002.

[8] Bradbeer, J., Barriers to interdisciplinarity: disciplinary discourses and student learning. *Journal of Geography in Higher Education*, 23(3), pp. 381-396, 1999.

[9] Appold, S., Competing to improve? A difficult terrain. *Proc. of the 1st Int. Conf. on Teaching and Learning in Higher Education*, eds. D. Pan, C. Wang, & K. Mohanan, National University of Singapore: Singapore, pp. 264-269, 2004.

[10] Frequently Asked Questions; International Association of Financial Engineers (IAFE). http://www.iafe.org/?id=faq.

[11] International Convergence of Capital Measurement and Capital Standards: A Revised Framework; Basel Committee on Banking Supervision, Bank for International Settlements, Press & Communications, CH-4002 Basel. http://www.federalreserve.gov/boarddocs/press/bcreg/2004/20040626/attachment.pdf.

[12] Computer Science: The Discipline; Denning, P. http://www.idi.ntnu.emner/dif8916/denning.pdf.

[13] Computing Curricula 2001 Computer Science Volume Final Report; Joint Task Force on Computing Curricula, IEEE Computer Society & Association for Computing Machinery (ACM). http://sigcse.org/cc2001/cc2001.pdf.

[14] Jacobs, H., (ed). *Interdisciplinary Curriculum: Design and Implementation*, Association for Supervision and Curriculum Development (ASCD): Alexandria, VA, 1989.

[15] Loepp, F., Models of curriculum integration. *Journal of Technology Studies: A Refereed Publication of Epsilon Pi Tau*, 25(2), pp. 21-25, 1999.