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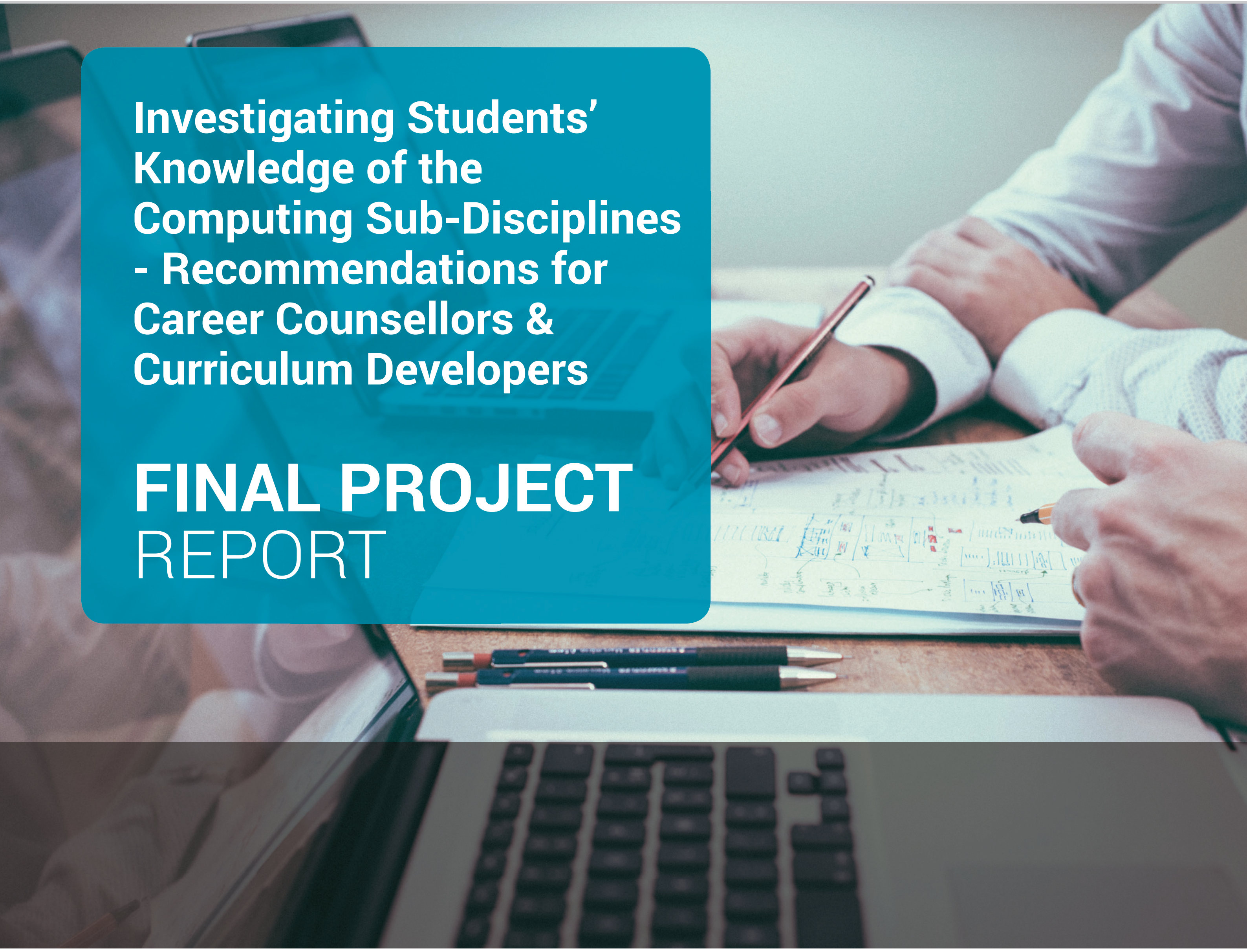

Investigating Students' Knowledge of the Computing Sub-Disciplines - Recommendations for Career Counsellors & Curriculum Developers

FINAL PROJECT REPORT

October 22, 2018

Developed with the support of

CERIC
Advancing Career Development in Canada
Promouvoir le développement de carrière au Canada

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PROJECT TEAM

Dr. Janet Miller is a counselling psychologist with expertise in post-secondary mental health issues and personal development. She celebrates career planning as encompassing all aspects of life, learning and work, and much of her research focuses on career, leadership and student success.

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Randy Connolly is a professor of computing whose teaching specialties are web development and technology and society studies. His research has oscillated between his two backgrounds of computer science and political science, and includes the teaching of web development, the general pedagogy of computing education, and the social effects of computing, especially, that of ICT on citizenship orientations. He is the author of three textbooks, the most recent of which is Fundamentals of Web Development, Second Edition, which is used by thousands of students at over a hundred universities worldwide. He has also authored 37 peer-reviewed papers and given over 20 international research presentations.

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Dr Faith-Michael Uzoka has taught Computer Science and Information Systems at various universities since 1992. He is a Full Professor (Computing) at Mount Royal University, Calgary; and has served as Adjunct Professor in a number of universities. Michael enjoys research and innovation and has published extensively in the following areas: medical information systems, multi-criteria decision support systems, computing personnel and disciplinary studies, technology adoption and innovation. He is on the editorial board/ program committees of several computing journals and conferences. He was a Canadian Commonwealth Scholar and a Carnegie African Diaspora Fellow.

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EXECUTIVE SUMMARY

State the over-arching need or gap that you identified that warranted such a project. How does this fill a 'gap' in the career counselling field?

The gap that we are aiming to address revolves around knowledge of the sub-disciplines within computing. These fields of study are quite diverse, and academic streams are defined early in an undergraduate's program of study. If a student is unclear about the nature of a sub-discipline, or has a misconception of what the field involves, then this will have a negative impact on career satisfaction, student retention and persistence. If a student makes a change in program, money and time are lost. Computer science tends to be the default computing field due to name recognition, but often students' interested in computing would actually be better suited to one of the other computing sub-disciplines.

The primary goal of this project was to investigate students' knowledge of the computing sub-disciplines and then to address gaps to help students choose programs that better align with their interests and expectations. Through this work we also aimed to contribute to ACM's review of the computing curricula and support career counselling and advising processes for students who are interested in these computing fields. This kind of career development work is innovative, and is considered to be leading-edge in the field.

Describe how the project meets CERIC's mission, vision and strategic priorities.

Our aim was to analyze and assess career understanding among students and faculty in the computing science disciplines so that we may improve career counselling practices relating to this field. As a result of this work we believe that prospective students will have more accurate information and be more informed when making career choices, which ultimately will lead to greater student success.

This project fits well with CERIC's mission and vision, in that it touches on all three of CERIC's strategic objectives: 1) This research aims to advance career development and build knowledge relating to careers in the computing disciplines; 2) It is multi-sectoral, working to bridge ACM guidelines with university curriculum and career counselling practices; and 3) Our research team includes both academic leaders and career counselling practitioners. Our hope is that this work will raise the profile of career development experts and also improve our career counselling interventions related to this field.

Describe the project in broad strokes – clearly state the problem you have identified needs to be addressed, the project purpose, goals, objectives and rough timelines.

The primary goal of this project was to investigate students' knowledge of the computing sub-disciplines and then to address gaps to help students choose programs that better align with their interests and expectations. The main outcome of this work is the publication: Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors (Connolly, Miller, & Uzoka, 2017).

This project was revised and extended across three years. Data collection was completed across sites in Canada, the United States, and Uganda involving students in computing and non-computing disciplines, and also computing faculty.

Through surveys we investigated participant's understanding of the five computing disciplines. Since the computing tasks and skills under investigation did not necessarily fall into discrete disciplinary partitions (ACM, 2005), we carried out a rank order analysis to determine how various skills fit with each of the computing sub-disciplines, followed by a cluster analysis of the disciplinary tasks based on the responses provided by our participants to provide a mapping of skills for each of the five areas. We also looked at how faculty perceived the various disciplines and we compared faculty responses against our student responses to investigate degree of overlap.

Results have been presented in several international forums including a panel presentation in Chicago, USA (October 2015), a conference presentation in Boston, USA (October 2016), a symposium presentation at the University of Ljubjana in Slovenia (January 2017), and during a keynote presentation at the Alberta Academic Advisors' Symposium in Calgary, Canada (November 2017). We will be presenting this work at Cannexus18 in Ottawa (January 2018), and have submitted presentation proposals for the International Congress of Applied Psychology (Montreal, June 2018) and the Canadian Association of University and College Student Services conference (CACUSS, Charlottetown, PEI, June 2018). Publications from this work have included Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines (Connolly et al., 2016), and the *Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors* (Connolly, Miller, & Uzoka, 2017). We have authored a submission for the Careering magazine (pending acceptance) and will aim to submit two more academic papers, one to an ACM journal and the other to the Canadian Journal of Career Counselling.

Talk about your target audience, stakeholders and any partners/ collaborators.

Stakeholders for this project have included:

- Post-secondary students in computing disciplines
- Prospective students considering careers in the computing fields (including high school students)
- Career practitioners (high school and post-secondary level, as well as private sector practitioners)
- Academic advisors (high school and post-secondary level)
- Psychologists focusing in career development or life design
- Faculty (professors, instructors) teaching in Computing fields
- The ACM curriculum review committees and affiliated discipline-specific groups

Clearly state the project deliverables.

The main product resulting from this work is the Guide (Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors by Randy Connolly, Janet Miller, & Faith-Michael Uzoka, 2017).

Other deliverables from this project including several international presentations including:

- panel presentation in Chicago, USA (October 2015),
- conference presentation in Boston, USA (October 2016)
- symposium presentation at the University of Ljubjana in Slovenia (January 2017),
- dissemination of the Guide as part of a keynote presentation at the Alberta Academic Advisors' Symposium in Calgary, Canada (November 2017).
- conference presentation at Cannexus18 in Ottawa (January 2018 - upcoming), and,
- webinar presentation through CERIC (date not yet finalized).

Please Note:
We have also submitted presentation proposals for the International Congress of Applied Psychology (Montreal, June 2018) and the Canadian Association of University and College Student Services conference (CACUSS, Charlottetown, PEI, June 2018).

Publications from this work have included *Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines* (Connolly et al., 2016), and the *Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors* (Connolly, Miller, & Uzoka, 2017).

We have also authored a submission for the *Careering* magazine (pending acceptance) and will aim to submit two more academic papers, one to an ACM journal and the other to the Canadian Journal of Career Counselling.

Was the project carried out as intended? If no, what was different? If yes, skip to next question.

This project was extended so that we could collaborate with the Mbarara University of Science and Technology and collect data from those students in Uganda.

The project was also extended due to a faculty sabbatical which delayed the completion of the Guide. We had initially intended to publish two Guides (one for students and the other for advisors), but after consultation from our stakeholders, we decided to publish one document (rather than publishing two Guides with significant content overlap).

We had intended to employ more students on this project. In the end we decided not employ a student to work on the visual layout of the Guide (as was our intention) given that Randy Connolly was able to devote some of his time and expertise to this work. The funds that were earmarked for graphic

Did the nature of any of the deliverables change over the course of the project? If so, how and why? If not, skip to the next question.

Nature of the deliverables did change - we produced one Guide (aimed at both prospective students and career advisors) instead of two separate ones. This decision was based on stakeholder feedback which showed us that students and Career Counsellors preferred to work from the same material.

Did the timelines change? If so, how and why? If no, skip to the next question.

Yes, timeline was extended to allow data collection to take place in Uganda, and due to a faculty sabbatical.

What was the anticipated outcome?

The intended outcome is to improve support for prospective students contemplating careers in the computing disciplines. The Guide that was produced from this project will provide counsellors (practitioners who provide psychosocial and therapeutic interventions on personal and career issues, including psychologists, psychotherapists and social workers), academic advisors (who provide guidance and advice regarding course and program selection), and prospective students with accurate discipline information that they can use prior to application for admission and/or prior to the time when they are required to choose their major. The outcome for students will be further support for their career selection process, so that they may make career choices that are more in line with their values and interests. The overall impact may be that students have the right information to make the right educational choices and thus avoid being inadvertently misdirected or enrolling in the wrong discipline. For curriculum development, through academic presentations, papers and consultation directly with the ACM's curriculum review committee, this project will assist leaders in creating further differentiation between the computing disciplines and support their communication with prospective students.

Were there changes to any other components of the project? If so, what was the nature of the change and what was its impact on the project?

The above mentioned timeline extensions provided opportunities to improve the deliverables of this project. Please see above commentary for details.

THE NEED FOR THE PROJECT

Our aim was to improve students' knowledge of the computing sub-disciplines, to assist faculty to revise their curriculum to align with the classifications defined by the Association of Computing Machinery, and to improve career counselling and advising processes for students who are interested in these computing fields.

Student enrollments in Information and Computer Technology (ICT) programs have alternated between over- and under-subscribed over the past twenty years. To help address this phenomena, the field of computing has undergone significant differentiation, resulting in five sub-disciplines (or career areas) which are distinct from one another.

To date, only a few studies have been completed which look at task understanding of the computing disciplines (Battig & Shariq, 2011; Courte & Bishop-Clark, 2007; 2009; Uzoka, Connolly, Schroeder, Khemka, & Miller, 2013). Results of these initial studies showed that the computing sub-disciplines do not have the clarity of division that is hoped for, and task ambiguity was mostly associated with tasks connected to larger or "real-world" technological/software projects. With the support of a CERIC partnership grant, this current project involved revising our existing survey tool (Uzoka et al., 2013), and administering it to a larger sample of undergraduate students. We extended this investigation to the USA and Uganda, and included student and faculty in our response pool. Results of this work have been presented and published in several forums reaching across our stakeholder groups (including current students, prospective students, academic advisors, career counsellors, faculty members, instructors, and curriculum developers).

PURPOSE, GOALS AND OBJECTIVES

The primary goal of this project was to investigate students' knowledge of the computing sub-disciplines and then to address gaps to help students choose programs that better align with their interests and expectations. Through this work we also aimed to contribute to ACM's review of the computing curricula and support career counselling and advising processes for students who are interested in these computing fields.

Did your originally proposed objectives change over the course of the project? If so, detail what objectives changed, how they changed and why they changed (provide sufficient detail to elaborate on specific internal and external factors).

No, the objectives did not change.

PARTNERSHIPS AND COLLABORATIONS

Briefly describe intended partnerships and collaborations

This partnership included a research group based out of Mount Royal University, partnership with CERIC, and collaboration with faculty-affiliates from the USA and Uganda.

If the project involved collaborating with another/other organization(s), including any not referred to in your proposal, please comment on the collaboration's effect on the project and how this process influenced you, your organization and your partner organization(s). What role did your collaborator(s) play? How often and in what manner did you meet with your collaborator(s)?

N/A

Similarly, if you engaged key informants, an advisory or steering committee, who were they and what role did they play in shaping and executing the project?

N/A

What non-financial supports did you request and/or receive from CERIC (eg. marketing, etc.)? How did this impact your project?

Throughout the life-cycle of this project we have received non-financial support from the Executive Director of CERIC in the form of direction, consultation and encouragement regarding opportunities that arose out of our research processes (e.g., opportunity to collaborate with the Mbarara University of Science and Technology), extensions of our project to support extended data collection and development of the Guide, review of publications including the "Red Fish Blue Fish" academic paper, the "Guide", and the article submitted to the Careering Magazine. We have also had support from CERIC regarding distribution of the Guide (via their website, Cannexus18, and distribution at conferences). CERIC is also arranging for us to present a national webinar in the new year, and has arranged for a "book signing" distribution event at Cannexus18.

ACTIVITIES AND RESEARCH METHODS

To determine the level of match between the students' disciplinary knowledge and the contents of courses taught by each computing discipline we administered surveys to sample populations of students in Canada, the USA and Uganda. The survey was revised based on our earlier work in this area (Uzoka, Connolly, Schroeder, Khemka, & Miller, 2013), and converted into an online platform. Since the computing tasks and skills under investigation did not necessarily fall into discrete disciplinary partitions (ACM, 2005), we carried out a rank order analysis to determine how various skills fit with each of the computing sub-disciplines, followed by a cluster analysis of the disciplinary tasks based on the responses provided by our participants to provide a mapping of skills for each of the five areas. We also looked at how faculty perceived the various disciplines and we compared faculty responses against our student responses to investigate degree of overlap. The project has included several dissemination activities, production of research papers and the Guide for prospective students and career advisors.

Detail your activities, milestones etc. and any changes therein over the project life-cycle. Consider a chronology of actual events/activities and milestones to tell the story of how your project unfolded.

December 2014

Notice of partnership grant awarded by CERIC

February 2015

Finalization of partnership contract between CERIC and Mount Royal University

March – April 2015

Paper-based survey converted to online platform; project submitted to MRU's Human Research Ethics Board (HREB) and to similar review body at Brigham Young University (approved at both sites); Application made to MRU's internal research grant (unsuccessful).

May – August 2015

Application for ethics clearance submitted to DePaul University (approved); collaboration and discussion with faculty underway at several institutions including: New Jersey Institute of Technology, University of Cincinnati, University of New Hampshire, Lakehead University, University of Calgary, Grant MacEwan University, Dalhousie University, and University of Waterloo.

September – December 2015

Data collection completed at several sites but many other sites unable to collaborate at this time due to faculty constraints (time, interest, funding). Applied for MRU Internal Research grant (unsuccessful); Attended SIGITE/ACM conference in Chicago, and delivered International Panel Presentation (Randy Connolly, Barry Lunt, Janet Miller, & Loreen M. Powell) "Towards a Better Understanding of the Different Computing Disciplines".

January – April 2016

Connection made with Mbarara University of Science and Technology (MUST) in Uganda; discussion with faculty at Lautech (Nigeria); Request for CERIC extension to support data collection in Uganda. North American data collected to date is analyzed; literature review updated.

May – August 2016

Ethics approval obtained from MUST, data collection completed at MUST. Data set includes students from all computing disciplines (CE - 24%; IS - 24%; SE - 18%; CS - 14%; IT - 10%), “other computing” areas (3%) and non-computing majors (7%). Data analysis of North American data proceeds and manuscript is submitted for publication.

September – December 2016

Attend SIGITE 2016 in Boston, and present findings to an international audience. Paper published in conference proceedings “Red Fish Blue Fish: Re-examining Student Understanding of the Computing Disciplines” (Connolly et al., 2016). Face-to-face research meeting held with Randy Connolly, Janet Miller, Faith-Michael Uzoka, Barry Lunt, Craig Miller, and Annabella Habinka - discussion of timelines, knowledge sharing and implications for impact discussed. Project extended to accommodate sabbatical of Prof. Connolly.

January 2017

Presentations made during invited symposium at the University of Ljubljana (Ljubljana, Slovenia).

February – April 2017

First draft of the “Computing Disciplines: Quick Guides” for prospective students and for career advisors are designed, written and produced, then disseminated for review by stakeholders. Decision is made to combine the Guides into one document for both prospective students and career advisors. Document is revised.

May – August 2017

“Computing Disciplines: Quick Guide for Prospective Students and Career Advisors” is released for review to CERIC and again to select groups of stakeholders (including members of the ACM curriculum review committee).

September – December 2017

Guide is revised and published on CERIC’s website as a free resource; paper copies of the Guide are printed and distributed at several conference venues; arrangements are made for the Guide to be distributed at Cannexus18, and via a CERIC webinar. Conference presentation proposals for several venues are submitted (e.g., ICAP in Montreal June 2018; CACUSS in Charlottetown in June 2018); Careering Magazine article submitted for publication (under review); Final report for CERIC drafted and submitted (under review).

FUTURE PLANS: January – December 2018

- Completion of Final Report for CERIC
- Presentation at Cannexus18 and distribution of the printed Guide; promotion of the digital Guide
- co-host CERIC Webinar (date TBA)
- Budget report will need to be submitted internally at MRU and budget account resolved/closed
- Translation of the Guide into French for Canadian distribution
- Direct distribution of the Guide to provincial teachers' associations across Canada (specifically to guidance counsellors)
- Collaboration with USA faculty with the goal of revising the Guide for an American audience
- Aim to present at ICAP (June 18) and CACUSS (June 18)
- Completion of two academic papers incorporating North American and African data – one for ACM publication (Transactions of Computing Education) audience and the other written for the Canadian Journal of Career Development
- Review of feedback regarding the Guide and possible revision aimed for September 2018

As applicable to your project, for each of your activities or milestone, detail factors that were helpful, factors that were challenging or presented obstacles and areas where changes were required as a result.

FACTORS THAT WERE HELPFUL

Excellent research team; consistent support from CERIC's Executive Director; financial support from CERIC's partnership grant program; support from stakeholders regarding data collection (including faculty in the USA and in Uganda), knowledge sharing, resource development and distribution of the Guide; access to CERIC's team for distribution of the Guide at Cannexus, via the webinar and via their onsite resource/publications webpage.

FACTORS THAT WERE CHALLENGING

- Data collection at North American sites was not as broad as we had intended due to difficulties securing on-site faculty support at many universities, partly due to perceived complexities and inertia around ethics approvals at different universities.
- Data collection in Uganda was challenging due to inconsistent internet access, the need to revert to paper surveys and then challenges associated with data entry, delivery of original paper surveys and complications with ethics review, transfer of funds to pay the research assistant, etc.
- Timeline was extended to accommodate more data collection and one faculty member's sabbatical. Development of the Guide and completion of two journal manuscripts was delayed.

Clearly state where activities differed or deviated from activities proposed in your application.

We have several deliverables that will be completed in 2018 including presentation at Cannexus18, intended presentations at ICAP 2018 and CACUSS 2018, a CERIC webinar and completion of two journal articles (one for the Canadian Journal of Career Development and the other for the ACM Transactions of Computing Education.

TIMELINES AND DELIVERABLES

This project was outlined as a two year project, but was extended by a year (spanning February 2015 to February 2018). The project was extended due to delays at the outset (re: finalization of partnership agreement between CERIC and Mount Royal University), unanticipated opportunities (e.g., opportunity to collect data in Uganda, opportunity to have the Guide reviewed by various stakeholder groups), and unanticipated interruptions (e.g., obstacles related to data collection at other North American universities, and a sabbatical of one of our lead research team members).

Were reporting and other deliverables given on time and what possible adjustments needed to be made to proposed timeline given outside considerations (e.g., ethics approval from outside agencies; unanticipated delays or interruptions).

As mentioned above, this project's timeline was extended by about a year due to several unanticipated opportunities and interruptions. The deliverables of the project were delayed as a result, but we also were able to give deliverables of higher quality as a result.

Describe the intended deliverables from your proposal. List in bullet form all of the project deliverables.

- Survey completed in a number of post-secondary institutions across North America
- Survey data analyzed and knowledge mobilized through academic conference and symposium venues
- Student's Guide to the Computing Disciplines
- Practitioner's Guide to the Computing Disciplines

If different from what was initially stated, specify and explain. Provide details of each project deliverable in the Appendix.

- Surveys were completed in a number of post-secondary institutions, but the project was revised to include data from African, American and Canadian universities. Due to data saturation we only included a sampling of Canadian and American universities.

- Knowledge mobilization included more venues than we had anticipated, including a panel presentation (Chicago, October 2015), international conference/symposium presentations. (e.g., Boston, 2016; Ljubljana, 2017), opportunities to distribute paper copies of the "Computing Disciplines Guide" to Advisors through the Alberta Academic Advising Symposium (Calgary, 2017) and at the upcoming Cannexus18 (Ottawa, 2018), invitation to submit an article for Careering Magazine (under review) and to co-host a webinar with CERIC (date in 2018 TBA). We have also submitted presentation proposals for the International Congress of Applied Psychology (Montreal, June 2018) and the Canadian Association of University and College Student Services conference (CACUSS, Charlottetown, PEI, June 2018).
- RE: Publications - Publications from this work have included Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines (Connolly et al., 2016), and the Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors (Connolly, Miller, & Uzoka, 2017). We aim to submit two more academic papers, one to an ACM journal (Transactions of Computing Education) and the other to the Canadian Journal of Career Development.
- Guide book was originally envisioned as two documents (one for students and one for advisors), but based on feedback from stakeholders we revised our vision and created one document for both prospective students and career advisors.
- Guide book was originally envisioned as downloadable PDF, but now has been made available in print as well.

Describe any deliverables including specific documents or learning materials developed over the course of the project. Detail the target audience(s) for each deliverable.

- Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines (Connolly et al., 2016) Target: academic audience of educators in computing disciplines; ACM audience
- Survey completed in a number of post-secondary institutions across North America
- Survey data analyzed and knowledge mobilized through academic conference and symposium venues
- Student's Guide to the Computing Disciplines
- Practitioner's Guide to the Computing Disciplines
- Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors (Connolly, Miller, & Uzoka, 2017). Target: prospective students, academic advisors, career counsellors, parents
- Various Conference Presentations Target: academic audiences, curriculum developers, academic advisors, faculty and instructors, career practitioners, career counsellors, career advisors, other post-secondary student service practitioners.
- Webinar, Careering Article (pending acceptance) Target: academic advisors, career practitioners, career counsellors, career advisors, other secondary andéor post-secondary student service practitioners.

If your project involved data collection, including surveys, focus groups, participant's feedback, quotes that informed product development, etc. provide some details – purpose of the data collection, what type of data was collected? Where was data stored?

This project used an online survey to gather data about students' understanding of the computing disciplines. Students and faculty were given a number of discipline-related tasks that they ranked as fitting or not fitting with each discipline. Our survey tool and methodology received approval from MRU's Human Research Ethics Board (HREB) and we received ethical clearance at each participating university.

Paper surveys were used in African sites due to inconsistent and unreliable access to the internet. These paper survey results were then entered into a spreadsheet by research assistants, and the original paper surveys were brought to us personally by the faculty affiliate from Mbarara University of Science and Technology. These paper surveys remain on site at MRU in a locked filing cabinet in the faculty office of one of our co-researchers (Michael Uzoka). Once data analysis and publication involving that data has been completed, those paper records will be shredded according to usual research protocols and procedures.

Feedback regarding the early versions of the Guide were obtained via email, individual consultation, informal interviews, and social media commentary. This data helped to inform our development of the Guide and have been incorporated where possible.

Were there any ethical considerations? Any challenges or setbacks? How did you mitigate these?

Our project received ethical clearance/approval from Mount Royal's Human Research Ethics Board (HREB) and from all other data collection sites. We faced some challenges having paper survey data entry from those surveys completed in Uganda, but all errors were addressed and the original (paper) surveys were delivered in person by our faculty affiliate to the SIGITE 2016 conference in Boston, MA. Those completed surveys are now stored on site at Mount Royal University.

If you had an opportunity to do this project again, are there things that you would do differently?

Overall this project went smoothly, although perhaps if we had to do it again we would not have waited for internal reviews at so many Canadian and American universities (which ultimately delayed our project substantially and did not result in as many partnerships we had anticipated). Overall though this project has been very satisfying and seems to have created a very positive impact. Connection with the ACM board through Barry Lunt was extremely useful and the results of the project have been well received.

MARKETING AND DISSEMINATION

How will the initiative be promoted and marketed to its intended audience?

RE: Promotion and dissemination of the Guide

- CERIC has posted the Guide on their website as a downloadable, free resource and has arranged to give a free printed copy to any delegate who attend Cannexus18 in January.
- Members of CERIC's staff have also distributed the guide at other career-related conferences and our research team distributed paper copies at the Alberta Academic Advising Conference (November 2017).
- At MRU we distributed approximately 200 print copies to prospective students and their parents through our University's open house, and additional copies are available within our Math and Computing department.
- We plan to disseminate electronic copies of the Guide to high school teachers and counsellors (Through their provincial associations) and to post-secondary practitioners through CACUSS (the Canadian Association of Canadian and University Student Services).
- We have submitted an article for inclusion in an upcoming Careering Magazine publication & plan to co-host a webinar with CERIC in the new year. Additional conference presentations and intended academic publications have been outlined in earlier sections of this report (e.g., ICAP 2018, CACUSS8, CJCD and ACM's Transactions).
- We have discovered that this Guide has already been printed or electronically distributed at other venues unconnected to authors, such as the 4th Annual Conf. on Computational Science & Computational Intelligence in Las Vegas and a UK-based assessment site. This indicates that the Guide successfully addresses a wide-spread need.

How were deliverables shared? How did you market and/or disseminate outputs/findings/learnings of the project?

SURVEY
We know that the survey was successful in that it was delivered in a variety of institutional contexts and our participation sample size is large enough to be reflective of this student body.

ACADEMIC PAPERS
We have already disseminated the results of this work (with data reflective of the North American populations we surveyed) and we aim to submit additional manuscripts using the North American and African data in the upcoming year.

GUIDE
This resource has already been disseminated and based on feedback from stakeholders, it has been revised and updated. We aim to have the Guide translated into French in the new year, and we are in discussions with an American colleague about adapting the Guide for use with American students.

ACADEMIC DISSEMINATION TO COMPUTING EDUCATORS

The best forum for reaching college and university educators in the computing fields is through one of the various computing education conferences, and we have already made two presentations as part of this project's dissemination strategy. We have had one academic paper published in the ACM's digital library and the Guide has been distributed to members of the ACM Curriculum Review Committee.

For Research Projects, tell us about the status of your research being published in the Candian Journal of Career Development (either already published at time of final report submission or publishing in the journal is in progress).

Publications from this work have included "Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines" (Connolly et al., 2016), and the "Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors" (Connolly, Miller, & Uzoka, 2017). We have also authored a submission for the Careering magazine (Miller & Connolly, 2018, acceptance pending) and we aim to submit two more academic papers in 2018 - one to the ACM journal Transactions of Computing Education, and the other to the Canadian Journal of Career Development.

What was your plan? What strategies did you use? What were critical factors that impacted the successful implementation of your plan?

Dissemination of this work has very much been supported by CERIC, the research team and collaboration with our diverse group of stakeholders.

Was the dissemination successful? How could you tell?

Dissemination of this project's findings has been multifaceted and ongoing.

Feedback to date has been very positive (based on feedback received at conferences, following presentations, through online discussion/comment fields, in person comments, emails from stakeholders, review by CERIC staff members, and review by Academic Advisors). We have had request to translate the Guide into French and we have been asked to revise the Guide for an American audience. We will gather comments from Cannexus18 delegates (through a users survey) and we will be interested in tracking downloads from the CERIC website. All feedback to date has indicated that the Guide is seen as a useful resource and we are very pleased to see it being distributed as a free printed resource (as well as a downloadable PDF).

As mentioned above, we have discovered that this Guide has already been printed or electronically distributed at other venues unconnected to authors, such as the 4th Annual Conf. on Computational Science & Computational Intelligence in Las Vegas and a UK-based assessment site. This indicates that the Guide successfully addresses a wide-spread need.

REVENUE GENERATION / COST RECOVERY

If you had developed strategies for to generating revenues within the project, describe these and speak to how you did in relation to how you expected to do (as per your proposal).

No revenues have been generated within this project.

EVALUATION AND MONITORING

Explain how you will know whether the project has achieved success.

Success of this work is measured through:

- Acceptance to have this work presented at peer-reviewed international conferences
- Number of invitations received to share the Guide and knowledge resulting from this research work at conferences, symposiums, meetings, webinars, etc.
- Successful publication in peer-reviewed academic journals
- Downloads of the Guide from the CERIC website
- Number of printed copies of the Guide that are distributed among stakeholders
- Formal and informal feedback from stakeholders regarding this project's outcomes

What evaluation tools did you use? How did you evaluate? Describe the inputs to the project, the process and the results, including the impacts.

This project has successfully produced the following deliverables:

Knowledge Sharing

- Panel presentation in Chicago, USA (October 2015),
- Conference presentation in Boston, USA (October 2016)
- Symposium presentation at the University of Ljubljana, Ljubljana, Slovenia (January 2017),
- Dissemination of the Guide as part of a keynote presentation at the Alberta Academic Advisors' Symposium in Calgary, Canada (November 2017).
- Conference presentation at Cannexus18 in Ottawa (January 2018 - upcoming)
- Webinar presentation through CERIC (date - TBA)

We have also submitted presentation proposals for the International Congress of Applied Psychology (Montreal, June 2018) and the Canadian Association of University and College Student Services conference (CACUSS, Charlottetown, PEI, June 2018).

In addition to the above-mentioned peer-reviewed venues, this work has been published in the ACM library under the title "Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines" (Connolly et al., 2016).

We have also completed the "*Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors*" (Connolly, Miller, & Uzoka, 2017) which is now available on the CERIC website (http://ceric.ca/publications/). Page visits and downloads should be trackable through webanalytics on this site.

We are awaiting notice of whether or not our article will be accepted for publication in an upcoming edition of Careering Magazine (Miller & Connolly). We also aim to submit two more peer-reviewed academic articles, reviews of which will also provide us with information on the success of this project.

Additional evaluation tools will include:

- Formal and informal feedback from stakeholders regarding this project's outcomes
- Demand for printed copies of the Guide
- User's feedback survey (which we will distribute at CERIC's upcoming webinar and during Cannexus18 as part of our conference presentation and "book signing" event).

Describe the connections between evaluation tools you used for the project and the goals you have identified.

The evaluation tools outlined above are in line with our project's goals and intended outcomes.

What specific marketing activities (website tracking; presentations; exhibits; blog posts; Twitter) were used in terms of project evaluation metrics?

Project evaluation metrics included (or will include): website tracking, paper publications distributed; accepted for presentation at peer-adjudicated conferences; successful publication in peer-reviewed journals/proceedings.

You provided three letters of support from key stakeholders. What impact did your project have on them? Was the impact different from what they anticipated from the project?

At the outset of this project, we submitted a letter of support from the Alberta Teacher's Association (Counselling section), and we have sent them communication intermittently through out the course of this work. We have sent them an electronic copy of the Guide for their distribution and review. We have invited comments from their members on the usefulness of this work and look forward to their feedback.

We also submitted a letter of support from our Mount Royal University Research Office. Unfortunately we did not successfully secure an internal research grant to support this project and thus our budget was adjusted based on our fiscal resources (which included support from CERIC and individual faculty member's professional development and/or personal funds). We are grateful to have had support from a staff member of our research office (Mr. Suman Pantra) who worked with us to insure that we were managing our funds appropriately.

Lastly, we included a letter of support from a member of the ACM executive. We have distributed electronic copies of the Guide to their curriculum development group and to members of the ACM Board of Directors. We have also published an academic paper (now available in the ACM digital library), and presented on the findings of this research project at two ACM-sponsored conferences. We hope that they will post the Guide on the ACM website and use it to inform their curriculum development processes.

IMPACT ASSESSMENT / OUTCOMES

Explain the intended outcomes from your proposal and describe data collections methods and tools.

The primary goal of this project was to investigate students' knowledge of the computing sub-disciplines and then to address gaps to help students choose programs that better align with their interests and expectations. Through this work we also aimed to contribute to ACM's review of the computing curricula and support career counselling and advising processes for students who are interested in these computing fields. This kind of career development work is innovative, and is considered to be leading-edge in the field.

To address this goal, we surveyed computing and non-computing undergraduates in three different countries to investigate students' understanding of the computing disciplines. Findings indicated that the computing disciplines do not have the clarity of division that the ACM had hoped for (Connolly, et al., 2015). In particular, we found that computing students had most difficulty making the distinction between IT and IS related tasks, and students need to understand that the CS field had less to do with software development than they might think. We concluded that we needed to provide students with more information about the SE role in designing, developing and implementing software, and help students to see CS as more focused on the theoretical foundations of information and computation.

In addition to one completed academic paper, several conference presentations and collaboration with the ACM task force on curriculum development, we have developed a research-informed publication designed to support career exploration into the computing disciplines. *Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors* (Connolly, Miller & Uzoka, 2017) describes the five computing disciplines in a way that we think will be meaningful to prospective students, parents and career advisors. This work has strengthened curriculum development at the ACM level, and we hope that the Guide will be of significant value to prospective students and their career advisors.

Data collection to assess the impact of this work includes measuring the uptake of the Guide (e.g., number of printed copies requested, number of conferences that distribute the Guide to their delegates and the number of delegates who receive the Guide, webanalytics from the CERIC website, distribution of the Guide by other organizations, associations, etc; acceptance of this work in peer-reviewed publications or conferences; formal and informal feedback from stakeholders including user survey to be distributed at Cannexus18, etc).

What were the actual outcomes of the project?

Outcomes of this project include greater awareness by students, parents, advisors and career counsellors of the computing disciplines. We hope that students will be better informed when making their educational choices as a result of this work, and that they will have the right information to make their best educational choice, and thus avoid wasting time or resources in a program that doesn't suit their interests. We also intend for this work to inform the ACM's curriculum review process and have already received feedback from committee members that the results of this research project have been valuable in that regard.

What were your measures of success? Be specific. For example, in the case of a website project, talk about the usability and navigability of the site, speak to the content of the site, etc. If tools or guides were being developed, provide examples of tools and plans for the use of the guide.

Measures of success include inclusion of our work in many peer-reviewed forums including conference presentations and publications and uptake of the Guide (both as a printed resource and through online web-analytic metrics).

In terms of impact, we have already had requests to translate the Guide into French, to adapt it for an American audience, and we have seen the Guide featured on other websites including this UK-based site (http://iagonline.org/computing-disciplines-in-canada-a-quick-guide-for-prospective-students-and-career-advisors). Feedback from ACM board members has also shown us that this work has had a positive impact.

Were there any unexpected outcomes or unintended consequences?

Interest in the Guide for an American audience has been an unexpected outcome and we were surprised to see the Guide featured on a site in Britain. We did not expect to see the Guide printed in such large quantities and we did not expect that the Guide would be distributed to delegates at Cannexus18!

KEY FINDINGS / INSIGHTS

Share your key findings from the project. Provide any insights and any learning from the project.

Through this project we surveyed faculty and undergraduate students from three different countries (Connolly, et al., 2016). We found that computing students had most difficulty making the distinction between IT and IS related tasks, and students need to understand that the CS field had less to do with software development than they might think.

We concluded that we needed to provide students with more information about the SE role in designing, developing and implementing software, and help students to see CS as more focused on the theoretical foundations of information and computation. This work informed creation of the Guide, which is now available for download on the CERIC website.

Provide any reflection on project implementation process and learnings from the project.

Overall this project has been very rewarding and the outcomes are already showing a positive impact. Working with CERIC has been terrific - they are an organized group of committed individuals and their enthusiastic support for this work has been very much appreciated.

Did the project partnership funding lead to any capacity-building within your organization? Within your community stakeholders?

This project partnership funding was essential to the success of this project. The funding did not create capacity-building within our University, but it has added resources that are valuable to our prospective students and to employees within our advising area, counselling services and Department of Math and Computing.

How might the learnings from the project impact your service, methods and future thinking?

The Guide has already had an impact on our services - it was distributed at our University open house event and feedback from employees, parents and prospective students was very favourable. The Guide is now available in our Department of Math and Computing and current students have given it positive reviews. Our academic advisors and our student counsellors also have copies of the Guide now, and we hope that they will use it to inform their work with students over the years ahead.

If the project involved collaborating with another/other organization(s), what lesson(s) did you learn about your collaboration process?

Through this project we did collaborate with several other universities in Canada, the USA and Africa. We have gained experience navigating through various systems relating to hiring of research assistants, addressing the ethical review processes, and connecting with faculty from various cultures, time zones and departments.

If your project included revenue generation/cost recovery strategies, what lessons did you learn?

N/A

Did you undertake any anticipated or unanticipated political activities with funds provided for this project partnership?

N/A

NEXT STEPS AND RECOMMENDATIONS

What next steps would you recommend to enhance work done through the project or contact information for those interested in their area of work or, again, future projects to continue to support evaluation?

Our next steps for this work include completion of manuscripts for publication and dissemination of this work through conference venues mentioned earlier in this Report. We recommend that the Guide be translated into French and that collaboration with national and international partners continue with the goal of distributing the Guide to high school audiences.

For more information on this project, or how it might be adapted to suit other disciplines of interest, please contact Dr. Janet Miller (jbmiller@mtroyal.c).

APPENDIX A

Publications from this work have included Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines

Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines

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ABSTRACT
This paper updates the findings of a multi-year study that is surveying major and non-major students' understanding of the different computing disciplines. This study is a continuation of work first presented by Uzoka *et al* in 2013 [11], which in turn was an expansion of work originally conducted by Courte and Bishop-Clark from 2009 [5]. In the current study, data was collected from 668 students from four universities from three different countries. Results show that students in general were able to correctly match computing tasks with specific disciplines, but were not as certain as the faculty about the degree of fit. Differences in accuracy between student groups were, however, discovered. Software engineering and computer science students had statistically significant lower accuracy scores than students from other computing disciplines. Consequences and recommendations for advising and career counselling are discussed.

Keywords
Information technology; computer science; information systems; software engineering; computer engineering; advising; career counselling

1. INTRODUCTION
From there to here, from here to there, computing disciplines are everywhere … and for good reason. The field of computing has expanded significantly over the past 20 years. The Association of Computing Machinery (ACM) has tried to manage the increasing complexity of computing by recognizing and articulating five distinct sub-disciplines within computing: computer science (CS), information systems (IS), software engineering (SE), computer engineering (CE), and information technology (IT). These different sub-disciplines are carefully described in their own ACM Curriculum Recommendations; the ACM Computing Curricula Overview Report of 2005 [1] provides a synopsis of each of these sub-discipline recommendation reports. The authors of the Overview Report recognized that while there is topic overlap in all the five sub-disciplines, each sub-discipline nonetheless has a unique and distinct academic identity.

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Our multi-year and multi-institutional study has been motivated to discover whether computing students have an understanding of these computing disciplinary identities and boundaries and to what degree student understanding mirror the official ones defined by the ACM. The value of this kind of study is twofold. For students, their initial understanding of the different computing disciplines is likely to play a large role in how they decide which (if any) computing program to register in. For computing faculty, the distinctions between the computing disciplines might seem more obvious; we would nonetheless benefit from knowing how the students' mental model of computing differs from (or agrees with) that of computing faculty.

2. RELATED WORK
In 2009, Courte and Bishop-Clark (C&BC) [5] surveyed undergraduate students' understanding of the differences between the five ACM-identified computing disciplines. Students from a variety of computing majors, as well as non-majors, were asked to associate job task descriptions with the best disciplinary fit. Their results suggest that students did not have a clear understanding of disciplinary scopes (especially the fields of SE and IT)–though major students unsurprisingly knew their discipline better than non-majors. These findings were validated by a subsequent study by Battig and Shariq [2], who also found that disciplinary differences were better understood by students at small, liberal arts-based institutions.

Other studies of perceptions about computing tend to focus solely on CS, or on "computing" generally, with no differentiation between the ACM-identified disciplines. An exception is a study by Helps, Jackson and Romney [7] which surveyed CS, IS, IT and non-computing majors at Brigham Young University regarding, among other things, their understanding of disciplinary differences between CS, IS and IT. It is interesting to note that a significant number of students from different computing majors often laid claim to disciplinary responsibility for tasks involving keywords such as "networking". A comprehensive literature review on this broad area can be found in our earlier paper [11].

Our previous study corroborated some of these other studies; we found that students were not always clear about the disciplinary fit of different computing tasks. Yet major and non-major students were often able to correctly equate tasks with the relevant computing discipline. However, the limitations of our previous work did circumscribe the generalizability of our conclusions. Our students were all from the same institution and, in terms of computing majors, were limited to CS or IT. This paper reports the results from a more comprehensive and varied student sample.

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3. METHODOLOGY

In the C&BC study that inspired our work, students were given 15 task descriptions and for each task they had to indicate which of the five disciplines were the best fit for that task. The main drawback to this approach is that the students had to choose a single discipline for a task, which does not capture the possibility of overlap between the disciplines. To address that drawback, our study allowed the participants to choose how much each task fit with each of the five disciplines using a five-point scale, with 0 being "Don't Know", 1 being "No Fit", and 5 being "Best Fit".

The 31 job-related tasks were the same as in our previous study. They included the 15 tasks identified by C&BC, plus 16 additional tasks added by the authors. The overall intent of the task questions was to find out if students understood the tasks associated with different computing disciplines. A complete list of the tasks contained in the questionnaire is presented in Table 1.

Table 1. Tasks Considered

#	Best Fit	Description
1	CE	Designs hardware to implement communication systems
2	CS, SE	Uses new theories to create cutting edge software
3	CE	Builds hardware devices such as iPods
4	IS	Is business oriented
5	SE	Focuses on large-scale systems development
6	IT	Integrates computer hardware and software
7	IT	Troubleshoots and designs practical technical applications
8	CS	Focuses on the theoretical aspects of technology
9	IS	Combines knowledge of business and technology
10	IT	Applies technology to solve practical problems
11	SE	Designs testing procedures for large-scale systems
12	IS	Selects computer systems to improve business processes
13	IT	Applies technical knowledge for product support
14	CS, SE	Utilizes theory to research and design software solutions
15	IS	Manages large scale technological projects
16	SE	Develops software systems that are maintainable, reliable, efficient, and satisfy customer requirements
17	IS,IT	Focuses on information, and views technology as a tool for generating, processing and distributing it
18	SE	Utilizes sound engineering practices to create computer applications
19	IT	Provides a support role, within an organization, to help others make the best use of its technical and information resources
20	CS, IT	Uses a wide range of foundational knowledge to adapt to new technologies and ideas
21	IS	Uses technology to give a business a competitive advantage
22	CE	Develops devices that have hardware and software in them
23	CS	Applies mathematical and theoretical knowledge in order to compare and produce computational solutions and choose the best one
24	CE	Focuses exclusively on hardware design, including digital electronics, with little or no involvement in software design
25	IT	Understands both technology and business, but with a focus more on the technical side
26	IS, IT	Uses programming skills to create or modify business solutions
27	IT	Develops or maintains web sites
28	SE, IS	Manages a team of software developers
29	IS, IT	Manages a company's computing department
30	IT	Evaluates and improves the usability (user experience) of computing systems
31	IS, IT	Works with an organization's data assets

The last five tasks were purposely ambiguous – they were five typical "real-world" computing job tasks that lacked the obvious signal words (i.e., "business", "system", "hardware", "theory", and "technology") of the C&BC tasks.

In our previous study, the authors decided among themselves what is the Best Fit discipline for each task question. Upon reflection, we realized this potentially predetermined the results; as well, the authors' understanding of "best fit" might be idiosyncratic and unrepresentative. As a result, we instead determined best fit by having faculty (n=13) from four universities (and four different computing disciplines) fill in the same survey as the students; we then used their responses to construct the disciplinary best fits shown in Table 1. (In particular, if the mean of the faculty response for a discipline for a given task question was 4 or higher, we added it as a best fit for the task).

Some of our student participants used paper forms, while others filled out an online version hosted on surveymonkey.com. Students from four universities participated: one from Canada, two from the United States, and one from Uganda. The results reported here are from the three North American universities; a more comprehensive follow-up paper to this one will have the space to integrate the unique results from the African participants.

4. RESULTS

4.1 Participants

After filtering out uncompleted surveys, our analysis was able to use 668 completed North American surveys. Of those who completed the survey, 80.3% were male and 19.7% were female. Table 2 lists some of the key demographic data.

Table 2. Partial Demographic Data

Variable	Options	%
Program of Study	CE	31.4
	CS	13.9
	IS	1.7
	IT	19.4
	SE	12.9
	Other Computing	7.0
	Non-Computing	13.7
Level of Study	Year 1	38.8
	Year 2	26.4
	Year 3	15.3
	Year 4	19.0
	Other	0.6
Prior Computing Experience	None	77.0
	< 2 Years	13.2
	2-5 Years	7.2
	More than 5	2.6

As noted above, this study examined the responses to 31 task questions. Each task was given a CE, CS, IS, IT, and SE rating between 0 and 5 by each participant, resulting in a total of 155 (31 × 5) task inputs. Our task data was not an ordinal Likert scale, but arguably an interval scale; as a consequence, we did not perform non-parametric analysis (as advocated by [8], though see contrary arguments by [4] and [10]). Instead we analyzed our response data parametrically using t-tests and one-way ANOVAs.

4.2 Comparison to Faculty Responses

As mentioned in the methodology section, one of the key ways this study differed from our previous study was our use of faculty answers to the same survey as a way to construct the disciplinary best fit of the different task questions. Full-time teaching faculty from university computing programs in the USA (n=9) and Canada (n=4) completed the survey and their interrater reliability was very strong (13 raters; $\alpha = .94$). Using these results, we can now compare, on a question-by-question basis, and on a discipline-by-discipline basis, how our students rated tasks relative to the faculty. For example, Figure 1 illustrates faculty versus student means on six selected tasks questions. Students by and large reflected faculty opinions, though they were almost always more cautious in assigning 1s (no fit) and 5s (best fit) to disciplines in comparison to faculty.

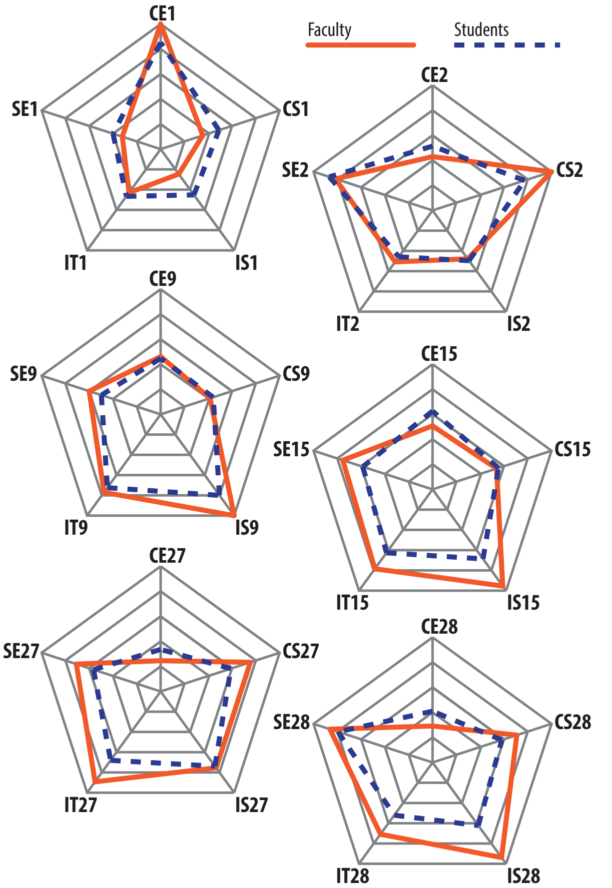

Figure 1. Sample Student vs Faculty Results

Student responses to tasks 2 and 9 (see Table 1 for task question text) are interesting. As recognized by our faculty respondents, both questions have cross-disciplinary best fits; it is encouraging to see that students were also able to perceive that certain tasks are not the sole purview of specific disciplines. Tasks 15, 27 and 28 are also interesting because the tasks are more uncertain in the sense they do not clearly belong to any specific computing discipline. In general, student responses for these types of task tended towards the median, indicating their uncertainty about how real-world tasks map onto the different computing disciplines.

4.3 Rank Order Analysis

The visual relationships shown in Figure 1 were more rigorously examined using rank order analysis [9]. This analysis method is especially well suited for interval data lacking objective measures of correctness (such as ours) [6]. A Rank Proximity Index was calculated (see Table 3) for each task based on a standardized (Z) score of proximity of ranking between the first and second ranked discipline. A positive Z-score implies that the ranking proximity is above the mean (0.0417), while a negative value implies that it is below the mean. A high Z-value implies that the discipline ranked first was distinctively determined to be the best fit for the given task, while a low value implies that though a discipline is ranked first, the second ranked discipline is considered 'very close' in terms of best fit for the given task.

For example, the Z-value of 4.1626 for task 3 clearly points to the distinctiveness of Computer Engineering as the best fit for task 3. On the other hand, a Z-score of 0.0068 for task 28 implies that the first and second ranked disciplines (SE and IS) are very close in terms of best fit relative to task 28.

Table 3. Rank Order Analysis

#	Discipline Ranking By Students (low #s indicates high task-discipline match)					Rank Prox. Index	Best Fit by Faculty	Match
	CE	CS	IS	IT	SE			
1	1	3	4	2	5	1.1266	CE	5
2	4	2	3	5	1	-0.2491	CS,SE	5
3	1	2	5	3	4	4.1626	CE	5
4	4	5	1	2	3	-0.2492	IS	5
5	5	4	1	2	3	-0.1091	SE	**3**
6	1	2	5	4	3	-0.2961	IT	**2**
7	5	3	4	1	2	-0.4730	IT	5
8	2	1	5	4	3	0.4886	CS	5
9	4	5	1	2	3	-0.2797	IS	5
10	4	5	3	1	2	-0.5192	IT	5
11	5	3	1	4	2	-0.5870	SE	4
12	5	3	1	2	4	-0.4181	IS	5
13	4	5	2	1	3	-0.0508	IT	5
14	3	2	4	5	1	-0.3879	CS, SE	4,5
15	3	5	1	2	4	-0.4324	IS	5
16	5	2	3	4	1	0.2171	SE	5
17	5	3	1	2	4	-0.4363	IS, IT	5
18	2	3	5	4	1	-0.1943	SE	5
19	5	3	2	1	4	-0.2232	IT	5
20	2	1	4	5	3	-0.4701	CS, IT	5
21	4	5	1	2	3	-0.3878	IS	5, 1
22	1	3	5	4	2	0.3271	CE	5
23	3	1	4	5	2	0.0911	CS	5
24	1	2	4	3	5	1.9933	CE	5
25	4	3	2	1	5	-0.5610	IT	5
26	5	3	1	4	2	-0.4311	IS, IT	5, 2
27	5	3	1	2	4	-0.4327	IT	4
28	5	3	2	4	1	0.0068	IS, SE	4, 5
29	5	3	1	2	4	-0.5216	IS, IT	5, 4
30	5	4	1	2	3	-0.5157	IT	4
31	5	3	1	2	4	-0.1879	IT	4

As is apparent from Table 3 and Table 4, the match between student and faculty rankings was remarkably close. While the student and faculty means varied (as shown in Figure 1), our students were able to relatively match the faculty's rankings in all but two task questions (shown shaded in Table 3). These two tasks ("Focuses on large-scale systems development", "Integrates computer hardware and software") are each arguably ambiguous about the disciplinary best fit, and, indeed, the standard deviation of the faculty means for each discipline for these tasks was low, indicating the faculty also had some uncertainty about the disciplinary best fits.

Table 4. Discipline Match Distribution

Match level	CE	CS	IS	IT	SE
Perfect (5)	4 (100%)	5 (100%)	9 (100%)	9 (69%)	5 (71.4%)
Good (4)	0 (0%)	0 (0%)	0 (0%)	3 (23%)	1 (14.3%)
Average (3)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	**1** (14.3%)
Fair (2)	0 (0%)	0 (0%)	0 (0%)	**1** (8%)	0 (0%)
Poor (1)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total Tasks	*4*	*5*	*9*	*13*	*7*

4.4 Program/Discipline Differences

What about program differences? Did students from certain disciplines answer the questions in different ways? Examining our one-way ANOVA analyses of the role that the students' program of study had on their task scores, we discovered that one of the biggest differences was that between CS and IT students (this will be explored further in section 4.5 below). As can be seen in the samples shown in Figure 2, CS students frequently had a narrower perspective on the disciplines in comparison to the IT students. For the more discipline-ambiguous tasks such as 14 and 28, the IT students were much more likely than the CS students to believe a given task could be handled by multiple disciplines. This should not be surprising. Tightly-defined impermeable boundaries are characteristic of well-established and convergent disciplinary communities, while newer, more epistemologically open-ended disciplines are often characterized by broader, more permeable boundaries [3].

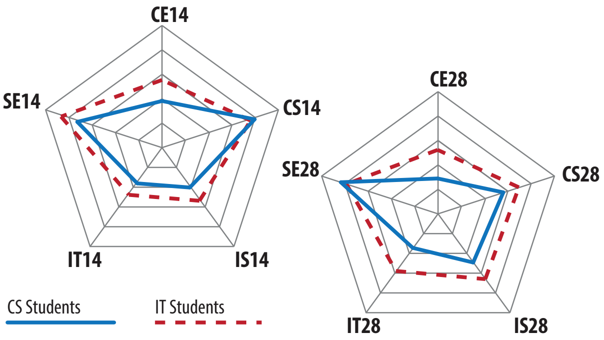

Figure 2. CS vs IT vs Faculty Opinions

4.5 Disciplinary Clusters

Based on the faculty responses, and confirmed by the students' rank order analysis, the 31 items were divided into five categories representing best-fits with each of the computing disciplines. Each cluster score contained items which faculty rated as fitting at a 4 (or above) on the five-point interval scale, thus some tasks were categorized into two discipline clusters.

Cluster scores were then calculated for each student participant by adding together the target discipline rating (e.g. CE rating) for each item assigned to this cluster (e.g., the CE cluster included items 1, 3, 22 and 24). These scores were totaled and averaged to create a CE-Cluster score.

An ANOVA investigating cluster score variation among students in various programs of study showed statistically significant (p<0.05) in all five cluster areas. These results are depicted in Figure 3.

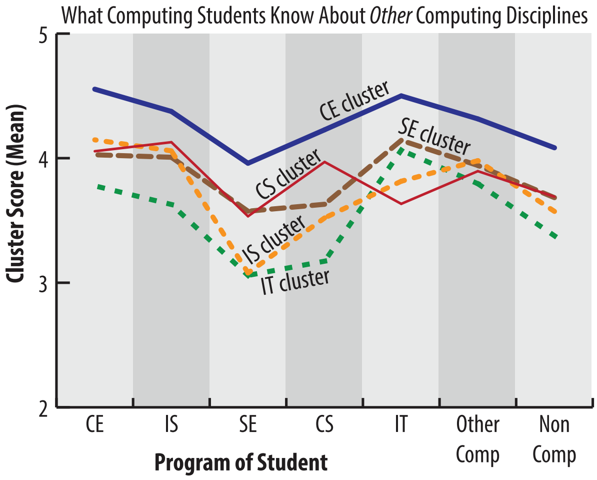

Figure 3: Discipline Cluster Scores by Program

An average of all discipline cluster scores yielded a total accuracy score, and again significant differences among students from the various programs was found, F (6, 350) = 6.178, p = 0.00. Post-hoc (Bonferroni) analyses showed that SE students scored significantly lower (M = 3.49) than their CE (M = 4.14) and IS (M = 4.08) peers (p < 0.001). A statistically significant difference was also found between CS students (M = 3.68) and the CE (M = 4.14, p < 0.05). Total accuracy scores for each program of study group are presented in Figure 4, along with a reference line showing the faculty accuracy score.

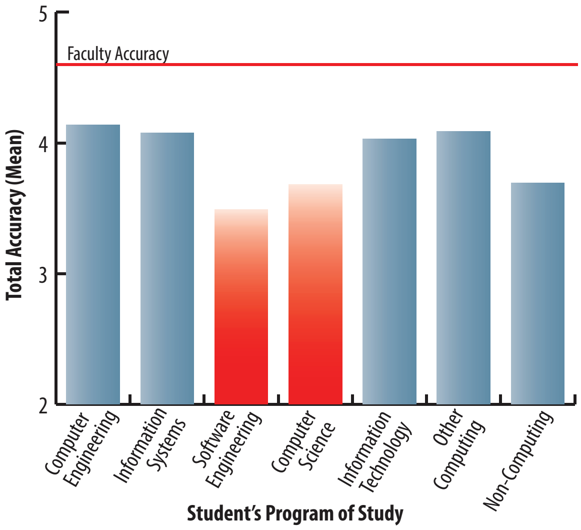

Figure 4: Total Accuracy Scores by Program

Looking at students grouped by year of study, there was a statistically significant difference in total accuracy scores among students in their first four years of an undergraduate program, F (3, 350) = 2.712, p < 0.05). Although post-hoc analysis (Bonferroni) did not reveal significant differences between groups, the trend appears clear: discipline understanding improves with study (see Figure 5 below).

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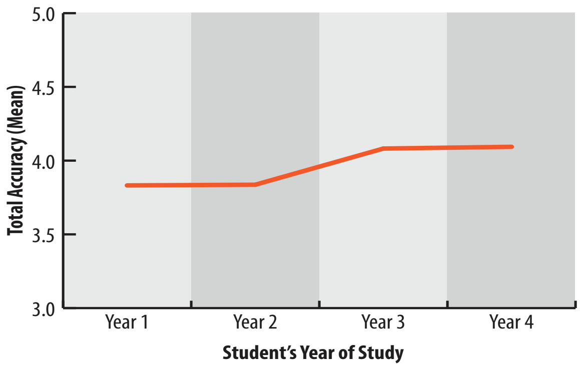

Figure 5: Total Accuracy Scores by Year of Study

5. DISCUSSION

The first phase of our project surveyed first-year students in two programs at a single undergraduate-only university. The second phase of our research, which has been chronicled in this paper, expanded the research to additional universities, to additional computing programs, and to students of all levels.

Like the earlier C&BC study, our results show that students are not always clear about the disciplinary "fit" of different computing tasks. However, by allowing students to specify a degree of disciplinary fit, our study showed that by and large students are able to get their discipline matches surprisingly close (though this was moderated by their experience level and their program of study).

As noted in section 4.3, student responses mirrored faculty responses in *direction* of fit but not in exact *quantity* of fit. That is, students in general were able to correctly recognize that a given task belonged more to certain disciplines, but were not as certain as the faculty about the degree of fit. This could be interpreted as meaning the students are less certain about disciplinary fit than the faculty. Since university faculty live and breathe disciplinary silos, it is natural that they would see disciplinary fit in a more extreme manner than students. Yet as noted in Becher and Trowler's classic study on academic disciplinarity [3], "some borders are so strongly defended as to be virtually impenetrable; others are weakly guarded and open to incoming and outgoing traffic: but in general a considerable amount of poaching goes on across all disciplines." Thus we should be willing to contemplate interpreting this student uncertainty more positively; perhaps students are actually more cognizant than faculty of the uncertain fit between the different computing disciplines and real-world computing tasks.

This study was intended, in part, to inform career counselling and academic advising practices to support students in making program choices that best fit their interests. Our data seems to be in line with the ACM's (2005) theoretical framework [1] (as shown in Figure 6) although CE appears to stand out as a more distinct discipline than is shown here.

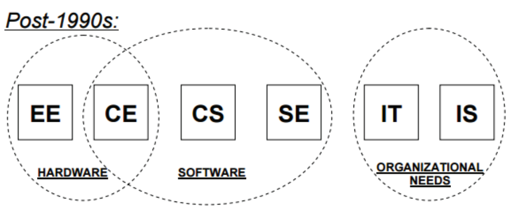

Figure 6: ACM (2005) Diagram

We tried to re-visualize this ACM diagram using our cluster data in Figure 7, and found that our results extend the ACM groupings. The CE grouping appears to have the most clearly defined task identity (as judged by both faculty and students); there is essentially very little overlap with the other computing disciplines.

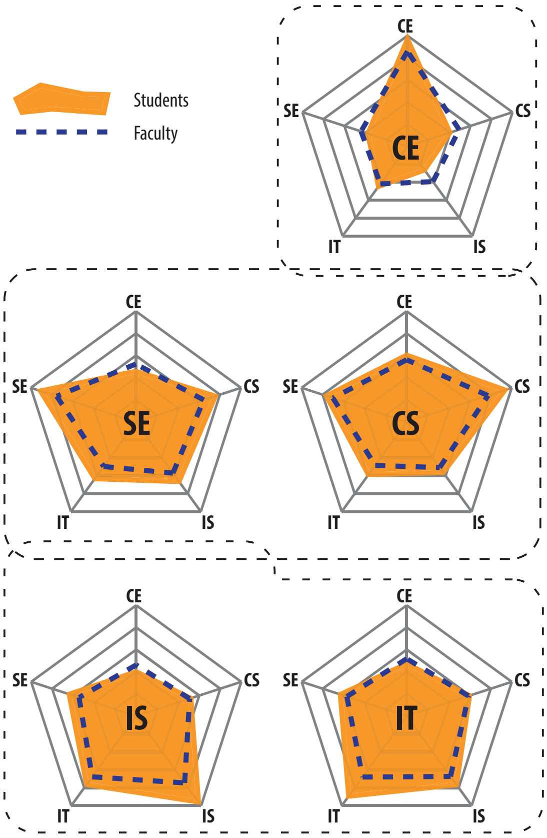

Figure 7: Discipline Groupings Revisited

Compare this to the CS and SE group. Not surprisingly, both students and faculty recognized that both disciplines shared best fit with both the CS and SE tasks. Similarly, students and faculty believed that IS and IT have overlapping task identities. Though not as noticeable, our data also indicated that IS, IT, and SE have some overlap in terms of task fittedness.

Our study results thus provide guidance for counsellors and advisors. It indicates that we should ideally use a two-step intervention process to support students in selecting the computing field that best suits their interests and abilities. In the first step, we should help students to identify the general computing area that is of most interest (CE, CS/SE or IT/IS), and then, in the second step, further define interests and clarify understanding within each of those areas.

As we work to support students to make the distinction between IT and IS, our focus should be on illuminating the differences each takes to business development, with one creating technological solutions to problems (IT) and the other striving to identify needs and efficiencies (IS). In the CS/SE area, it seems students need to understand that the CS field has less to do with software development than they might think. We need to provide them with information specifically about the SE role in designing, developing and implementing software, and help them to

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understand that the CS focus is more on the theoretical foundations of information and computation. We believe that linking these nuances with individual interests, values and goals will increase student graduation rates and career satisfaction.

6. LIMITATIONS

The main limitation of our study is similar to that of the C&BC study that inspired it: namely, if the task descriptions are too obvious, then this would compromise the statistics and any conclusions drawn from them. As well, the five disciplines did not have the same number of tasks for which the discipline was the best fit.

Another limitation was that we did not have nearly enough IS students in our study, nor enough females. This meant that our comparative analysis of task perceptions of students lacks some generalizability when it comes to our IS and gender results. This limitation will be addressed in the near future as we gather survey data from additional institutions.

While not exactly a limitation, the large number of ratings (31 tasks × 5 disciplines = 155 ratings) resulted in a steady response rate deterioration as students progressed through the survey. This trend can be seen quite clearly in Table 4.

Table 5. Response Distribution Deterioration

Task Number	Response Rate (%)	Blank (%)	Don't Know Response (%)
1	72.33	27.67	0.02
2	72.09	27.91	5.78
3	71.86	28.14	7.06
4	71.80	28.20	6.89
…			
28	60.70	39.30	6.22
29	59.39	40.61	6.28
30	58.75	41.25	5.29
31	58.78	41.22	6.69

While the inter-rater reliability score of our faculty reviewers was remarkably high, IT and IS fields were highly represented in our sample of faculty reviewers; moving forward we plan to broaden our faculty representation so that we have roughly equal representation from all five computing disciplines. Lastly, in this paper our data is comprised only of students from North America, and understanding how computing disciplines are understood on an international level would be of considerable interest. Our data from African students arrived too late to be integrated into this paper.

7. CONCLUSION

Students and faculty share a general understanding of the computing disciplines, and for students, discipline understanding becomes more refined as they proceed through their undergraduate experience. To support incoming students and prospective students in their career choice, our data shows that guidance practitioners will need to provide more specific information about the CS/SE distinction and the IT/IS distinction. Though more analysis in this area is still needed, it appears that this need is more acute for prospective female students, and educational materials about these fields could be developed with these directions in mind. As well, within the computing disciplines, it appears that the SE and CS students could benefit especially from having more knowledge about the other computing disciplines. Examining the ACM Curricula Reports for each discipline, we could not help noticing that the ACM IT, IS, and CE model curriculum reports each have a section right at the start reflecting on their discipline's relationship to the other five disciplines. The CS and SE reports do not!

It is true that disciplinary boundaries are not immutable but are socially constructed (and thus can change over time). Nonetheless, we believe that having a realistic understanding of the identity and boundary of not only one's own discipline but also that of neighboring disciplines is likely to improve students' ultimate satisfaction with their discipline. Understanding the unique contributions each of these disciplines makes to the field of computing will be of benefit to students when selecting undergraduate majors, and we expect that more informed choices up front will lead to less attrition and greater student success.

8. ACKNOWLEDGMENTS

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APPENDIX B

International Panel Presentation delivered at SIGITE/ACM conference in Chicago

Towards a Better Understanding of the Different Computing Disciplines

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Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education

General Terms: Design, Human Factors, Languages.

Keywords: Information technology, computing sub-disciplines, advising, career, computing curricula.

1. SUMMARY

The field of computing has undergone significant differentiation over the past twenty years, resulting in several distinct computing sub-disciplines. After extensive consultation with experts and industry stakeholders, the ACM [1] defined five distinct sub-disciplines within the computing field: computer science (CS), information systems (IS), computer engineering (CE), software engineering (SE), and Information technology (IT). While these areas are unique, they are not completely discrete, and there seems to be ambiguity around which tasks fit into which sub-discipline. The ACM has made significant efforts to define these in terms of expected program content and by the outcomes and skills required to prepare students for the dynamic labor market. Nonetheless, research [4,5,6,9] shows that there is a need for an even clearer understanding of these sub-disciplines by the academic community, by guidance and career counsellors, and by, of course, prospective students.

This panel will address some of the issues and problems involved with communicating how the computing disciplines overlap and diverge. The panelists straddle several computing disciplines as well as provide insight into the advising issues faced by non-computing guidance and career counsellors. We hope that through a lively dialog between the audience and the panelists, all participants will come away with improved understanding and techniques for communicating the differences between the different computing disciplines.

SIGITE'15, September 30 - October 03, 2015, Chicago, IL, USA
ACM 978-1-4503-3835-6/15/09.
http://dx.doi.org/10.1145/2808006.2808016

2. BARRY LUNT

The ACM Sub-Disciplines

Students in high school who are interested in computing generally have two options: computing (which is usually keyboarding and word processing), and computer science. This changes dramatically when they enter post-secondary education, where computing includes the five disciplines recognized by the ACM, and formalized in the model curricula of each discipline, along with the document *Computing Curricula 2005: The Overview Report*. These six documents, fully vetted and formalized by their respective professional associations (ACM, AIS, and IEEE-CS), constitute an excellent description of computing at the post-secondary level. A summary of these documents will be presented and discussed.

Barry Lunt was the chair of both SIGITE committees that produced the IT 2008 Model Curriculum; as well as the editor of that document. He is presently serving on the ACM executive committee and full committee for the IT 2017 revision of this document. He is a founding member of SITE, which later became SIGITE. He has been teaching in the IT field for 14 years, and at the college level for 28 years. He holds a PhD in occupational and adult educations and is a full professor of Information Technology at Brigham Young University (Provo, UT), where he has been teaching for 23 years.

3. LOREEN POWELL

The Position of Information Technology

The information technology (IT) field is vast, dynamic and in demand. The demand for IT jobs consistently exceed the supply of available IT employees. Yet, across the nation a consistent trend of low enrollments in IT and related programs is occurring. Why? The IT field is unlike finance, marketing, management, and accounting in that it is a relatively new field that is constantly evolving due to the new developments in technology at various levels of use. People also have a good understanding of the job functions with of a marketer, manager, or accountant. An overall summary regarding understanding of the different IT job functions, IT job opportunities, and IT disciplines will be presented and discussed.

Loreen Marie Powell, Ph.D. is an Associate Professor of Information and Technology Management (ITM) at Bloomsburg University of Pennsylvania. She has over 10 year of higher education teaching experience within the Information Technology (IT) field.

4. JANET MILLER

Counselling Perspective

The demand for computing graduates is on the rise, yet enrollment in computing majors continues to decline. Research from social cognitive career theorists has shown that students are avoiding computing disciplines because they feel either unable to succeed (lack of self-efficacy) or because they believe their interests are not in line with these fields of study [2, 7]. Unfortunately career counsellors, academic advisors, parents and students have a narrow understanding about what the field of computing may offer and thus the ability to accurately assess a students' interest in these fields is limited. Strategies for enhancing our understanding of the computing sub-disciplines and improving students' computing-related self-efficacy will be discussed along with implications for career counselling interventions.

Janet Miller, Ph.D. is a registered psychologist, an Associate Professor, and the Chair of Student Counselling at Mount Royal University. She is also the lead researcher on a CERIC-funded project titled "Investigating Students' Knowledge of the Computing Sub-Disciplines: Recommendations for Career Counsellors and Curriculum Developers".

5. RANDY CONNOLLY

Research and Future Directions

To date, only a few studies have been completed which look at task understanding of the different computing sub-disciplines [2,4,5,6,8,9,10]. All of these suggest that students do not always have a clear understanding of disciplinary scopes and that a significant number of students from different computing majors often laid claim to disciplinary responsibility for particular tasks or knowledge areas. For instance, an area such as networking might be claimed to "belong" to CE, CS, or IT.

We hope to gain better insight into future directions through a sustained conversation with the panel audience about developing best practices for communicating sub-disciplinary distinctions to future students and counsellors.

Randy Connolly is a Professor in the Math and Computing Department at Mount Royal University. He is the author of the textbook Fundamentals of Web Development (Pearson, 2014) and is currently working on the same CERIC-funded project as Janet Miller.

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APPENDIX C

Article featured in *Careering* Magazine

Not Every Computer-Related Job Is IT

Understanding computing disciplines to help advisors guide students in choosing the **right career path**

By Janet Miller and Randy Connolly

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When you are out at a party, meeting new people, how do you answer the question "What do you do?"

Do you respond with a job title, or do you describe some of the functions of your work? Do you try to describe the impact of your responsibilities, or do you talk about the education or training that led you into this career? In some career sectors, it can be especially difficult to answer this question in a way that provides a satisfying answer. Computing is one of those sectors.

Explaining the computing sector to better advise for computer-related careers

Jobs like *Software Developer* or *Gaming and Multimedia Specialist* might sound familiar, but when we are asked to really describe what these people do, many career advisors struggle to have clear answers about the tasks of the job and the recommended post-secondary training. Answering the question "What do you do?" gets even more uncertain when we are talking about fields like bioinformatics, IT security or computational science. To make it even more complicated, the field of computing has expanded rapidly over the past decade, and we know that many current computing students will take on jobs that do not even exist today. Despite this complexity and breadth, online career counselling resources typically treat computing as a single discipline, usually labelled "computer science." Research and practice have shown that computer science programs are often the first to be recommended to prospective students, and based on the nearly 50% attrition rate reported by these programs (Beaufouef & Mason, 2005; Chen & Soldner, 2013), we know that this is not the best fit for all students interested in computing.

"... the field of computing has **expanded rapidly** over the past decade, and we know that many current **computing students** will take on jobs that do **not even exist** today."

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This is similar to working with a student who is interested in the food and beverage industry but who is only exploring careers related to cooking. With support from a knowledgeable advisor, this prospective student may also consider food and beverage-related marketing, business administration, bartending, front-of-house service work, sales, construction, skilled trades, accounting or interior design. Helping this student to engage in study at an applied institute for culinary training might be the best fit, or alternatively, a university degree program focused on public relations and communication skills might be more in line with their actual industry-related interests.

Despite the fact that computer-related careers are the paradigmatic work of the 21st century, surprisingly little is known about the range of work people can do within this field. Perceptions of computing are especially shaped by stereotypical portrayals in film and television (insert mental picture of cubical work or darkened basements, of hackers and programming geeks, here). Constraints we face as career advisors when working to support career exploration in the computing disciplines include these media-reinforced clichés, and access to only generalized information about this complex and growing field.

Distinct sub-disciplines, sub-specialties and numerous possible educational paths

The Association of Computing Machinery (ACM) has acknowledged the increasing complexity of computing by articulating five distinct disciplines within computing: computer science (CS), information systems (IS), software engineering (SE), computer engineering (CE) and information technology (IT). These different sub-disciplines are carefully described in their own ACM Curriculum Recommendations. These five disciplines in turn have a number of sub-specialities that have resulted in dozens of possible educational paths for students interested in computing.

Our research with computing and non-computing undergraduates in three different countries indicated that computing students had the most difficulty making the distinction between IT and IS-related tasks, and that students need to understand that the CS field had less to do with software development than they might think. We concluded that we needed to provide students with more information about the SE role in designing, developing and implementing software, and help students to see CS as more focused on the theoretical foundations of information and computation.

With the generous support of CERIC project partner funding, we developed a free research-informed publication designed to support career exploration into the computing disciplines. *Computing Disciplines: A Quick Guide for Prospective Students and Career Advisors* describes the five computing disciplines in a way that we think will be meaningful to prospective students, parents and career advisors.

Each discipline is outlined through a brief description, and then we provide an "outside view" of the discipline (more of what we might say as a way of introducing ourselves at a party), and an "inside view" of what this area of work might involve. We have made the Quick Guide visual and invite prospective students to see themselves doing the tasks associated with each kind of career. The diagrams for each area visually describe its tendency towards either the applied or the theoretical aspects of computing – a perspective that easily connects with theories of personality and measure of career interests. Career practitioners can review "on-the-job tasks" with interested students, as well as typical core courses that the student could expect to encounter in college or university. Working backwards from job titles, career advisors can help students to consider pathways available to reach that goal. We understand that for students, their initial understanding of the different computing disciplines may play a large role in whether or not they decide to register in a computing program. The guide assists students to create a narrative of their career path that goes beyond the typical "computer science" label.

Our hope is that this resource will be a pleasure to read, easy to work with, and effective for supporting exploration into the diverse world of computing. For more information on the guide or to access a free download, please visit ***ceric.ca/computing.*** ■

AUTHOR BIOS

Dr Janet Miller *is a Counselling Psychologist with expertise in post-secondary mental health issues and personal development. She celebrates career planning as encompassing all aspects of life, learning and work, and much of her research focuses on career, leadership and student success. In addition to working at Mount Royal University for nearly 20 years, she is the Editor of* Kaleidoscope, *a Certified Trainer with the Centre for Suicide Prevention and an accomplished keynote speaker. She can be reached at janet.miller@hotmail.com.*

Randy Connolly *has been teaching at Mount Royal University since 1997. He is the author of three textbooks, the most recent of which is* Fundamentals of Web Development, Second Edition, *used by thousands of students at over 100 universities worldwide. He has also authored 34 peer-reviewed papers and given over 20 international research presentations. He is on the editorial boards of the two main journals for computing education* (ACM Transaction on Computing Education *and* ACM Inroads*). He can be reached at rconnolly@mtroyal.ca.*

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