

Mathematics and Quantitative Reasoning Task Force 2011 Final Report

University of Washington Bothell

Linda Simonsen, Professor, Science & Technology; Chair
Erin Hill, Acting Director, QSC; Associate Chair
Annette Anderson, Curriculum Development Director
Alexandre Barchechat, Lecturer, IAS and CUSP
Colin Danby, Professor, IAS
Cinnamon Hillyard, Assistant Professor, IAS
Allison Hintz, Assistant Professor, Education
Peter Littig, Assistant Professor, Science & Technology
James Miller, Associate Professor, Business
John Rasmussen, Senior Lecturer, IAS
Jamie Shirley, Lecturer, Nursing
Carol Zander, Principal Lecturer, CSS

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Executive Summary of Key Recommendations

On January 4, 2011, Vice Chancellor Susan Jeffords charged the Mathematics and Quantitative Reasoning Task Force (MQRTF) to convene during Winter Quarter, 2011, in order to formulate recommendations on how UW Bothell could best move forward in initiatives for mathematics and quantitative reasoning across the curriculum. The task force established the following recommendations:

1. **Request that the General Faculty Executive Committee (EC) support the development and offering of the undergraduate degrees in mathematics and quantitative reasoning (i.e., Mathematical Reasoning and Visualization (IAS), Bachelor of Science in Mathematics (S&T), and Minor in Mathematics (S&T)).**
2. **Request funding for new faculty hires in the areas of mathematics and quantitative reasoning as the degree programs, outlined in this document, mature.**
3. **Encourage continued cross-campus coordination of upper-level mathematics and quantitative reasoning courses and a mechanism for sharing information across campus and optimizing resources.**
4. **Recommend the adoption of the following courses prefixes for UWB mathematics and quantitative reasoning courses: BISM RV (IAS), STMATH (S&T), BMATH (CUSP).**
5. **Request that FOCUS continue to monitor mathematics teaching and assessment of courses with the BMATH prefix (CUSP).**
6. **Recommend that UWB academic programs adopt the QR initiative as outlined in this document in recognition that quantitative reasoning is an essential skill for all college graduates.**
7. **Request the TLC devote resources to support faculty integrating QR into their courses as outlined above, including seeking external funding for this support.**
8. **Request resources for the development and implementation of a campus-wide assessment instrument to evaluate student quantitative reasoning as outlined in this document.**
9. **Request that GFO Executive Committee annually review the progress towards the campus goals in quantitative literacy outlined in this document.**
10. **Request resources to fund an annual QR Institute and QSC faculty fellowships.**
11. **Request resources to hire a QSC Manager and a QSC Research and Statistics Associate.**
12. **Request resources to support the QSC director to participate in local and national conversations regarding QR education and develop a Pacific Northwest Consortium of math and quantitative support centers.**
13. **Request that a committee be formed to further investigate best practices for supporting a diverse student population, including students who are ELL, in mathematics and quantitative reasoning.**
14. **Request that a permanent subgroup of FOCUS devote time and resources to developing and monitoring policies to support students who are underprepared in mathematics and quantitative reasoning.**

Introduction

On January 4, 2011, Vice Chancellor Susan Jeffords charged the Mathematics and Quantitative Reasoning Task Force (MQRTF) to consider how UW Bothell could move forward in initiatives for mathematics and quantitative reasoning across the curriculum. More specifically, the task force was charged with recommending a three- to five-year strategic plan for the teaching and learning of mathematics and quantitative reasoning across UW Bothell's academic programs by the end of Winter Quarter, 2011, with respect to the following:

- I. **Build an inventory of current practices and emerging initiatives that will provide a clear picture of how programs currently teach and assess mathematics and quantitative reasoning (including statistics, current "QSR" requirement, and placement);**
- II. **Identify a short list of degrees or curricula that can be developed in a phased approach over the next five years, with consideration for ways to leverage existing resources and faculty expertise; and**
- III. **Identify what UWB will need to do to accommodate an increasingly diverse student population, including students who are English language learners and those who are quantitatively underprepared.**

Mathematics and quantitative reasoning courses are a critical component in many programs of study at UWB. The MQRTF, comprised of members representing all such programs, provided an important opportunity for cross-program dialogue on best practices in the teaching and learning of mathematics and quantitative reasoning. To guide our discussions we adopted the definition of "*quantitative reasoning*" articulated by the Association of American Colleges and Universities, and the working definition of "*mathematics*" found on Wikipedia:

***Quantitative Reasoning** is a "habit of mind," competency and comfort in working with numerical data. Individuals with strong QR skills possess the ability to reason and solve quantitative problems from a wide variety of authentic contexts and everyday life situations. They understand and can create sophisticated arguments supported by quantitative evidence, and they can clearly communicate those arguments in a variety of formats (using words, tables, graphs, mathematical equations, etc., as appropriate).*

***Mathematics** is the study of quantity, structure, space, and change. Mathematicians seek out patterns, formulate new conjectures, and establish truth by rigorous deduction from appropriately chosen axioms and definitions.*

With respect to **Charge I** this report includes a discussion of the current programmatic practices and initiatives in mathematics and quantitative reasoning, including the QSR requirement and current assessment practices.

Many students enter UWB with a desire to further their study in the area of mathematics and quantitative reasoning. To this end, the MQRTF discussed potential options for distinct, but

complementary, degrees in IAS and S&T. Faculty in IAS are proposing an Option in Mathematical Reasoning and Visualization. Faculty in S&T are proposing a Minor in Mathematics and a Bachelor of Science in Mathematics. The MQRTF also discussed the Quantitative Reasoning Across the Undergraduate Curriculum initiative. The report on **Charge II** includes summaries of the degrees and curricula, paying particular attention to the cross-curricular coordination of mathematics and quantitative reasoning courses. This section also include a detailed discussion of the QR initiative and the expanded role of the Quantitative Skills Center (QSC). Building on the excellent work already being done in these areas, the task force was able to think strategically about, and make recommendations regarding, campus-wide goals and coordination.

Finally, the MQRTF also provided an important opportunity for cross-program dialogue on how UW Bothell can best meet the needs of a growing campus and increasingly diverse student body. The report on **Charge III** includes a brief summary of our discussions and recommendations regarding support for English language learners (ELL) and the mathematically underprepared.

Charge I: Build an inventory of current practices and emerging initiatives that will provide a clear picture of how programs currently teach and assess mathematics and quantitative reasoning

Summary of Mathematics and Quantitative Reasoning Across UWB

Math and QR are prevalent in all degree programs at the University of Washington Bothell. All degree programs in Business, S&T, and CSS as well as the Environmental Studies, Environmental Science, STS, and MAPS degree programs in IAS are inherently quantitative because they have a calculus/pre-calculus prerequisite as well as multiple quantitative courses as part of their graduation requirements. In addition, the degree programs in Nursing and Education as well as the SEB, CP, and GST in IAS also require at least one significantly quantitative course for graduation. The extent of the offerings in each program is summarized in Table 1 below and specifics can be found in the MQRTF appendix.

Table 1: *Frequency of QSR-designated courses and courses with significant mathematical content*

Degree Program	Count
CUSP	23
Business	39
CSS*	8
Education	4
IAS	23
Nursing	1
S&T*	7

* However, many more CSS and S&T courses have some level of QR.

Additionally, several mathematics and quantitative reasoning courses (i.e., Calculus, Statistics and Linear Algebra) serve multiple programs of study offered at UWB. See the MQRTF appendix for more details regarding course offerings.

The diversity of the QR and mathematics on campus is reflected in the support of students in those classes at the QSC. Over the past year, the QSC has seen over 5,000 student visits in almost 100 different courses. They service a wide range of courses including those developing QR skills with freshman (such as pre-calculus and calculus) to graduate level courses in business and policy studies, and everything in between. The QSC provides tutoring services for traditional mathematics and statistics courses and a wide range of science, business, economics, and computing courses.

Current Quantitative and Symbolic Reasoning (QSR) requirement

Currently, the University of Washington requires students to complete one course that has been designated as “Quantitative and Symbolic Reasoning” or QSR. The requirement is meant to help students learn to use numerical or symbolic methods to assess the relationships among ideas, to demonstrate competency in using mathematical or logical methods to solve applied problems. However, the designation of a course as QSR is at the discretion of the curriculum committee at the time the course is initially reviewed. Further, there is no monitoring that future iterations of such a course continue to have quantitative components. (Details about this requirement can be found at: <http://www.washington.edu/students/ugrad/advising/aif/qsr.html>)

Current Mathematics and Quantitative Reasoning Assessment Practices

With the onset of the CUSP program in 2006 UWB designed its own QR and Math placement exam. The mathematics faculty and QSC staff graded these paper exams each summer. Not only were the results given to students as a guide for math placement, but the faculty also used the exam as a way to design and refine the new entry-level math courses. However, as the size of the freshman class grew, this option of assessment became unfeasible; both students and administration requested online access and standardization of testing with other WA 4-year colleges. In Fall 2010, UWB adopted the statewide placement exam instead. Currently, the effectiveness of this exam is being reviewed.

Charge II: Identify a short list of degrees or curricula that can be developed in a phased approach over the next five years, with consideration for ways to leverage existing resources and faculty expertise

Degrees in Mathematics and Quantitative Reasoning

Two UWB Programs are currently developing undergraduate degrees with mathematics and quantitative reasoning content (the most recent versions of these proposals can be found in the MQRTF appendix):

Mathematical Reasoning and Visualization (IAS)

A proposal for an option in Mathematical Reasoning and Visualization transited the initial stages of formal IAS review (IAS Curriculum Committee, IAS Program Council, IAS faculty) in February and March 2011, and was also discussed and critiqued in MQRTF meetings. If approved, this degree would begin as an option under the B.A. in Interdisciplinary Studies. It could later transition to a freestanding B.A., with the additional stages of approval that requires.

Bachelor of Science in Mathematics (S&T)

This degree resembles a standard mathematics curriculum with a focus on preparing future secondary mathematics teachers, but could expand over time to address other mathematics options. A proposal for a Bachelor of Science in Mathematics has gone through the initial phase of review in S&T in March 2011, and it was also discussed in the MQRTF meetings.

Minor in Mathematics (S&T)

This degree resembles a standard mathematics minor with a focus on offering a “value-added” credential to students currently majoring in highly mathematical fields (i.e., EE, CSS). A proposal for a Minor in Mathematics has gone through the initial phase of review in S&T in December 2010, and it was also discussed in the MQRTF meetings.

It is to be expected that these degree proposals will change as they transit program, campus, UW, and state approval processes, as well as informal consultations across campus. Relevant to this report is that these degrees, if approved, would:

- Add to the already-rich variety of UWB degrees that draw on lower-level mathematics courses. This connects to recommendations for supporting teaching in the CUSP mathematics courses.
- Potentially share some upper-level courses, such as game theory or graph theory. We recommend that faculty curricular decisions be informed by cross-program consultation, and that the campus adopt as a goal the greatest possible sharing of courses.
- Facilitate the offering of courses useful to non-majors.
- Help to build a campus culture in which mathematics is prominently visible, and richly linked to other areas of study.

Recommendations:

- 1. Request that the General Faculty Executive Committee (EC) support the development and offering of the undergraduate degrees in mathematics and quantitative reasoning (i.e., Mathematical Reasoning and Visualization (IAS), Bachelor of Science in Mathematics (S&T), and Minor in Mathematics (S&T)).**
- 2. Request funding for new faculty hires in the areas of mathematics and quantitative reasoning as the degree programs, outlined in this document, mature.**
- 3. Encourage continued cross-campus coordination of upper-level mathematics and quantitative reasoning courses and a mechanism for sharing information across campus and optimizing resources.**

Mathematics Course Prefixes

Currently, three programs on campus offer mathematics courses. We think it is important for such courses to be designated as such, especially as our students' transcripts are reviewed at other institutions. The MQRTF supports the following course prefixes:

BISMRV – Mathematics courses being offered and supported through the IAS program.

STMATH – Mathematics courses being offered and supported through the S&T program.

BMATH – Mathematics courses offered and supported through CUSP that serve multiple degree programs, these include, "Functions, Models, and Quantitative Reasoning" (currently BCUSP123 and a prerequisite for the calculus series) and our first year calculus sequence (currently BCUSP124/125/126).

The September 2010 report of the CUSP Implementation Committee, charged by the VCAA to implement GFO/EC Recommendations, wrote:

As the institution reshapes itself, we also want to emphasize the need for continued coordination of the first-year experience across campus and therefore propose ongoing consultations between CUSP and the programs on hiring, assessment, faculty development, and the inclusion of best national practices for first-year education. FOCUS should take the lead in providing this coordination and articulating both annual and strategic priorities. As one aspect of this, FOCUS should be charged to establish assessment priorities and processes for all the lower division classes, regardless of whether those are housed in CUSP or in the academic programs. The assessment process would include the Discovery Cores, Writing and Communication, Math and Quantitative Reasoning, and the electives representing the Areas of Knowledge (NW, IS, and VLPA). Such an assessment would, in consultation with the relevant programs, develop a review protocol based on the learning objectives, which would inform the teaching of future iterations of the courses. All of these measures would enable us to continue to create a strong cross-campus lower-division culture of teaching and related activities.

We recommend that FOCUS continue to assess mathematics teaching under the BMATH prefix (as designated above), and that the assessment be integrated into an ongoing effort to promote innovative teaching at this level, drawing in as many students as possible and enabling their success. It is especially in these courses that the campus needs to provide resources to help students with a range of backgrounds and preparations. If we are successful, we will encourage students who had seen mathematics as limiting their options to consider pursuing degrees with more mathematical content, as well as raising the level of mathematical competence across all UWB students.

Recommendations:

- 4. Recommend the adoption of the following courses prefixes for UWB mathematics and quantitative reasoning courses: BISMRV (IAS), STMATH (S&T), BMATH (CUSP).**
- 5. Request that FOCUS continue to monitor mathematics teaching and assessment of courses with the BMATH prefix (CUSP).**

Quantitative Reasoning (QR) Across the Undergraduate Curriculum

Quantitative reasoning (QR) is an essential skill for college graduates. Indeed, QR is listed as one of the essential learning goals of the *Association of American Colleges and Universities* and is a vital component of the 21st Century Campus Initiative of Innovation. (See: <http://www.aacu.org/leap/vision.cfm>) We recommend that UWB develop a systematic plan to increase student competence and comfort in applying quantitative concepts. This initiative should reach all undergraduate students and should be driven by two main goals:

- 1) To create a campus culture that values quantitative reasoning and cultivates quantitative literacy as an essential competence of an educated citizen.
- 2) To graduate students who astutely employ quantitative reasoning to better understand important issues and to make better-informed personal and organizational decisions.

Quantitative Reasoning Curriculum Development at the Lower Division

Building upon CUSP's Quantitative Literacy learning goal already in place, students will be required to develop quantitative reasoning skills across the undergraduate curriculum. This goal will be made clear at the outset of students' educational careers. Specifically, we suggest:

Deliberate Attention to QR in the Discovery Cores (DC): For DC courses that are not designated as QSR, we suggest as a goal that a majority of the DC courses incorporate some quantitative work. To support this effort, the QSC Director would work with FOCUS to offer workshops and work one on one with Discovery Core faculty to find places to naturally incorporate QR (e.g., working with data).

Lower Division Applied Quantitative Reasoning Course: We should develop one or more applied quantitative reasoning courses (100-level). These courses would focus on the use of QR to understand important social issues and to make informed personal choices. For example, a course might examine issues in personal finance, nutrition, public opinion polling, public health, racial profiling, or unemployment and the job market. These courses would immerse students in the analysis of problems that interest them.

Quantitative Reasoning Curriculum Development in Degree Programs

In addition to supporting the curriculum development in CUSP outlined above, we request each degree program consider requirements such as those described below:

Lower Division QR Requirement: Every student should be required to complete a one-quarter course in mathematics, statistics or quantitative reasoning. This requirement could be satisfied by pre-calculus, calculus, statistics, or by completing an Applied Quantitative Reasoning course (discussed above). These courses introduce students to quantitative concepts that can be applied and further developed in upper division courses.

Upper Division QR Requirement: Every undergraduate student should pass at least one quantitative reasoning course beyond the lower division requirement described above. To satisfy this QR requirement, a course would have at least one major assignment that combines critical reading, quantitative reasoning, and writing. In particular, students should critically evaluate quantitative

evidence and arguments in others' arguments and integrate quantitative information and arguments in their own writing.

Devoted Resources for Required Courses: The QSC Director and academic directors should be willing to devote resources to faculty willing to develop and require the above course. Programs themselves should prioritize needs/interests for such help and request support from the high level of QR expertise available on campus and nationally.

Quantitative Reasoning Faculty Development

While some faculty have considerable experience developing quantitative reasoning competencies, support for faculty development will encourage full and enthusiastic faculty participation. In conjunction with the Teaching and Learning Center, the QSC Director should design and organize QR pedagogy workshops to be available to all faculty. These workshops should draw on the expertise of our current faculty as well as outside experts. The TLC could further offer money to faculty to attend conferences to present their work on QR pedagogy. Additionally, UWB should seek funding for innovative QR initiatives from public and private foundations for faculty to upgrade their current courses and develop new ones.

Assessment of Quantitative Reasoning Learning Outcomes

A common assessment instrument should be adopted (across programs) to evaluate student quantitative reasoning. The assessment plan should include the following features:

- a. The assessment should evaluate both QR skills and attitudes towards QR.
- b. To the extent possible, our assessment should use established instruments developed and tested at other schools. Many of these are proven instruments with well-established psychometric properties.
- c. We should implement a longitudinal study that follows students through their undergraduate experience, assessing their QR skills and attitude at three points: 1) the beginning of the freshmen year, 2) the beginning of the junior year and 3) completion of the senior year.
- d. To establish baseline measurements, we should pilot our assessment tool with a cross-sectional study in Spring 2011 (graduating seniors) and Fall 2011 (entering freshmen and entering juniors).

Faculty trained in assessment of learning in conjunction with UWB's office of educational assessment should be responsible for this assessment plan.

Attention to Quantitative Reasoning on Faculty Governing Boards

We request that GFO Executive Committee annually review the progress towards the campus goals in quantitative literacy outlined in this document. While program faculties will ultimately establish learning goals for their courses, the QSC director can examine the QR research and initiatives at other schools to suggest promising possibilities. The EC can also review current UWB offerings to determine which courses presently promote QR learning goals. This committee could also identify (in clear operational terms) the critical quantitative insights and competencies that our students should master.

Recommendations:

- 6. Recommend that UWB academic programs adopt the QR initiative as outlined in this document in recognition that quantitative reasoning is an essential skill for all college graduates.**
- 7. Request the TLC devote resources to support faculty integrating QR into their courses as outlined above, including seeking external funding for this support.**
- 8. Request resources for the development and implementation of a campus-wide assessment instrument to evaluate student quantitative reasoning as outlined in this document.**
- 9. Request that GFO Executive Committee annually review the progress towards the campus goals in quantitative literacy outlined in this document.**

Expanded role of Quantitative Skills Center (QSC)

Currently, the Quantitative Skills Center (QSC) meets a range of quantitative needs including assisting underprepared students, enhancing the quantitative skills and reasoning of students and faculty, and providing an interdisciplinary environment in which to collaborate and converse. The suggestions below will require expansion of the Center to increase and widen the effective support of students and faculty across the campus to meet the goals outlined above. It is especially important for QSC resources to keep pace with the rapid changes occurring in the STEM and statistics fields, including the degree programs proposed above.

UWB should assist the QSC in the acquisition of resources to fund an Annual QR Institute, e.g., during the Summer Quarter. The Institute should be hosted by the QSC Director and would include a cohort of faculty with the goal of upgrading current courses and fully integrating QR across the UWB curriculum as outlined in this document. Fellowships should be funded for UWB faculty to work within the institute as well as work with the Center as consultants, to meet on syllabi, and to go into classes to fully support and advocate QR on the campus.

In addition to the institute, additional suggestions for expanding and improving the QSC include:

- Hiring a QSC Manager as soon as possible to oversee the daily operation of the Center;
- Hiring a quantitative research and statistics associate to meet the growing need of statistics literacy and methods across all programs. The associate would provide support with data collection, analysis, and visualization projects for students at all levels as well as faculty members. The associate would also work with the Office of Research Support by providing statistics and data support for individuals seeking funding;
- Funding the QSC Director to engage in local and national QR conversations including attending and presenting at QR education and assessment conferences;
- Supporting the Director to form a Pacific Northwest Consortium of math and quantitative Centers. These conversations will help to support QR on the UWB campus by establishing best practices, and they will provide a platform to share the successes of UW Bothell.

Recommendations:

10. Request resources to fund an annual QR Institute and QSC faculty fellowships.
11. Request resources to hire a QSC Manager and a QSC Research and Statistics Associate.
12. Request resources to support the QSC director to participate in local and national conversations regarding QR education and develop a Pacific Northwest Consortium of math and quantitative support centers.

Charge III: identify what UWB will need to do to accommodate an increasingly diverse student population, including students who are English language learners and those who are quantitatively underprepared.

Accommodating Diverse Learners

UW Bothell has a history of educating diverse learners. Not only is it one of the most ethnically diverse universities, but as a primarily commuter campus, we have a high percentage of “non-traditional” students (i.e., veterans, returning students). UWB has recently formed a diversity council “established to coordinate and guide ongoing progress in fulfilling the commitment to diversity” at the campus level (<http://www.uwb.edu/diversity/initiatives/diversitycouncil>). Further, UWB has successfully introduced the Dream Project and Academic Transition Project to recruit and support a more diverse student population.

One avenue for supporting diverse learners within the QSC has been to staff diverse tutors. The Center’s tutors currently have an age range from 19 to 50+, the ethnicities of the tutors continues to include: Caucasian, Chinese, Korean, Vietnamese, various African countries, Icelandic, Russian, and Indian to name a few, and the tutors have included non-traditional students. The diversity of the tutors has been invaluable for knowledge of foreign languages and culture, which is an integral part of communication. A subcommittee that includes experts in the field should investigate further support of ELL students.

As this task force did not have sufficient time to address these issues fully, we recommend that a committee be charged to investigate best practices in mathematics and QL education. We suggest that this committee include the QSC director, members of UWB’s diversity council, faculty involved with the Dream and Academic Transition Projects, and scholars knowledgeable about diversity in STEM education.

Accommodating Quantitatively Underprepared

The high percentage of students entering college who are not ready to succeed in college level mathematics is a national crisis. In the state of Washington alone, it is estimated that 45% of students who enter the state colleges place into pre-college (remedial) level mathematics courses. At UWB, 40% of students assessed scored less than 60% on the state adopted math placement test. Currently, most of those students are being asked to take a basic algebra course before proceeding on with their required math courses. However, some (those scoring more than 50%) have been allowed to take pre-

calculus with the additional requirement of taking a 2-credit learning strategies course in conjunction with pre-calculus.

Given the depth of this problem, we recommend that a permanent subgroup of FOCUS devote time and resources to developing and monitoring policies to address this problem. This committee should pay special attention to the national and state efforts including funding opportunities, to address these issues including the State of Washington's *Transition Math Project* (<http://www.transitionmathproject.org/>) and the Carnegie Foundation's *QuantWay* and *StatWay* initiatives (<http://www.carnegiefoundation.org/problem-solving/developmental-math>). In addition, the task force recommends that this committee look at the effectiveness of the 2-credit supplemental course, the possibility of peer mentors, and online assessment systems such as ALEKS (<http://www.aleks.com/>) to address these needs.

Recommendations:

- 13. Request that a committee be formed to further investigate best practices for supporting a diverse student population, including students who are ELL, in mathematics and quantitative reasoning.**
- 14. Request that a permanent subgroup of FOCUS devote time and resources to developing and monitoring policies to support students who are underprepared in mathematics and quantitative reasoning.**

References

Assessment and Learning in Knowledge Spaces, (<http://www.aleks.com/>)

Association of American Colleges and Universities, Essential Learning Outcomes, <http://www.aacu.org/leap/vision.cfm>

Carnegie Foundation for the Advancement of Teaching, <http://www.carnegiefoundation.org/problem-solving/developmental-math>

Mathematical Association of America, CUPM Curriculum Guide 2004, http://www.maa.org/cupm/curr_guide.html

Transition Mathematics Project, <http://www.transitionmathproject.org/>

Appendix

Mathematics and Quantitative Reasoning Courses Across UWB

CUSP		
Course #	Course Title	QSR
BCUSP 110	Discovery Core I: The Natural World	Yes
BCUSP 116	Discovery Core II: The Natural World	Yes
BCUSP 121	Algebra	No
BCUSP 122	Introduction to Elementary Functions	No
BCUSP 123	Functions, Models, & Quantitative Reasoning	Yes
BCUSP 124	Calculus I: Origins and Early Developments	Yes
BCUSP 125	Calculus II: Foundations and the Emergence of Modern Analysis	Yes
BCUSP 126	Calculus with Analytic Geometry III	No
BCUSP 127	Learning Strategies in Mathematics	No
BCUSP 130	Mathematics: A Practical Art	Yes
BCUSP 140	Scientific Journeys	Yes
BCUSP 142	General Chemistry	Yes
BCUSP 143	General Physics	Yes
BCUSP 144	General Physics	Yes
BCUSP 145	General Physics	Yes
BCUSP 149	Mechanics	Yes
BCUSP 150	Electromagnetism and Oscillatory Motion	No
BCUSP 151	Waves	No
BCUSP 152	General Chemistry	No
BCUSP 157	General Learning Strategies for General Chemistry	No
BCUSP 162	General Chemistry	No
BCUSP 176	Introduction to Global Economy	Yes
BCUSP 200	Introduction to Microeconomics	Yes
BCUSP 201	Introduction to Macroeconomics	Yes
BCUSP 237	Organic Chemistry	No
BCUSP 238	Organic Chemistry	No
BCUSP 239	Organic Chemistry	No

Business		
Course #	Course Title	QSR
BBUS 210	Principles of Financial Accounting	No
BBUS 211	Principles of Managerial Accounting	No
BBUS 215	Intro to Business Statistics	Yes
BBUS 310	Managerial Economics	No
BBUS 350	Business Finance	No

BBUS 361	Intermediate Accounting I	No
BBUS 362	Intermediate Accounting II	No
BBUS 373	Cost Accounting	No
BBUS 454	Investments	No
BBUS 455	Futures and Options	No
BBUS 463	Advanced Financial Accounting	No
BBUS 500	Quantitative Business Methods	No
BBUS 502	Quantitative Methods and Business Statistics	No
BBUS 503	Financial and Managerial Accounting	No
BBUS 504	Economics for Business Leaders	No
BBUS 505	Financial Management	No
BBUS 541	Advanced Corporate Finance	No
BBUS 543	Investments	No
ELCBUS 301	Business Statistics	Yes
ELCBUS 310	Managerial Economics	No
ELCBUS 350	Business Finance	No
ELCBUS 454	Investments	No
ELCBUS 455	Futures and Options	No
ELCBUS 463	International Finance and Trade	No

CSS		
Course #	Course Title	QSR
CSS 105	Interdisciplinary Information Technology	Yes
CSS 106	Computer Animation	Yes
CSS 161	Fundamentals of Computing	Yes
CSS 162	Programming Methodology	Yes
CSS 225	Physics and Chemistry of Computer Components and Their Manufacture	Yes
CSS 263	Programming and Discrete Mathematics	No
CSS 330	Topics in Mathematics for Software Development	No
CSS 342	Mathematical Principles of Computing	No
CSS 343	Data Structures and Algorithms	No
CSS 421	Introduction to Hardware and Operating Systems	Yes
CSS 450	Computer Graphics	No
CSS 451	Computer Graphics	No
CSS 455	Introduction to Computational Science and Scientific Programming	No
CSS 458	Fundamentals of Computer Simulation Theory and Application	No
CSS 502	Discrete Mathematics and Algorithms	No

Education		
Course #	Course Title	QSR
BEDUC 419	Knowing, Teaching, and Assessing in Mathematics	No
BEDUC 559	Curriculum, Instruction, and Assessment in Secondary Science and Mathematics I	No
BEDUC 560	Curriculum, Instruction, and Assessment in Secondary Science and Mathematics II	No
BEDUC 579	The Power and Beauty of Mathematics	No

IAS		
Course #	Course Title	QSR
BES 301	Science Methods and Practice	Yes
BES 303	Environmental Monitoring Practicum	Yes
BES 311	Environmental Chemistry	Yes
BES 318	Hydrogeology	Yes
BES 439	Computer Modeling and Visualization in Environmental Science	Yes
BES 459	Compost and Organic Soil Amendments	Yes
BES 460	Water Quality	Yes
BIS 202	Critical Reasoning	Yes
BIS 230	Mathematical Thinking for the Liberal Arts	Yes
BIS 231	Linear Algebra with Applications	Yes
BIS 232	Using, Understanding, & Visualizing Quantitative Data	Yes
BIS 250	How Things Work: Motion and Mechanics	No
BIS 232	How Things Work: Electricity & Invention	No
BIS 315	Understanding Statistics	Yes
BIS 329	Topics in Mathematics Across the Curriculum	No
BIS 350	The Concept of a Number	Yes
BIS 381	The History of Life	Yes
BIS 388	The Philosophy and Science of Quantum Mechanics	Yes
BIS 477	Topics in Quantitative Inquiry	Yes
BISGST 324	International Political Economy	Yes
BISSKL 377	Quantitative Reasoning	No
BPOLST 501	Public Finance and Budgeting	No
BPOLST 502	Statistics for Policy Studies	No

Nursing		
Course #	Course Title	QSR
BNURS 403	Evidence Based Practice and Nursing Inquiry	Yes

S&T		
Course #	Course Title	QSR
BST 293	Cryptography	No
BST 293	Game Theory	No
BST 390	Probability & Statistics in Engineering	No
BST 300	Foundations of Modern Math	Yes
BST 307	Introduction to Differential Equations	Yes
BST 293	Linear Algebra	No
BST 324	Multivariate Calculus	No

EE		
Course #	Course Title	QSR
BEE 215	Fundamentals of Electrical Engineering	No
BEE 233	Circuit Theory	No
BEE 235	Continuous Time Linear Systems	No
BEE 271	Digital Circuits and Systems	No
BEE 331	Devices and Circuits I	No
BEE 332	Devices and Circuits II	No
BEE 341	Discrete Time Linear Systems	No
BEE 361	Applied Electrodynamics	No
BEE 417	Digital Communication	No
BEE 442	Digital Signal Processing	No

Overlapping Program Mathematics Requirements

COURSE	PROGRAM/DEGREE						
	EDUC (MEd)	S&T	EE	CSS	IAS	BUS	NURS
CALCULUS I	X	X	X	X	X	X	
CALCULUS II	X	X	X	X			
CALCULUS III	X	X	X				
MULTIVARIATE CALCULUS		X	X				
LINEAR ALGEBRA	X	X	X	X			
PROBABILITY AND STATS	X	X	X				
STATS	X			X	X	X	X
DIFFERENTIAL EQUATIONS		X	X				
HISTORY OF MATH	X	X					
GEOMETRY	X	X					
MODERN ALGEBRA	X	X					
ABSTRACT ALGEBRA	X	X					
DISCRETE MATH	X			X			

Mathematical Reasoning and Visualization (IAS)

March 10, 2011

DRAFT FOR DISCUSSION AND CONSULTATION

Proposal for an Option in

Mathematical Reasoning and Visualization

Interdisciplinary Arts and Sciences

University of Washington Bothell

A new option for Interdisciplinary Arts and Sciences (IAS) students at the University of Washington Bothell (UWB) is proposed to start in Fall 2012. The option in Mathematical Reasoning and Visualization (MRV) will join existing options in the Interdisciplinary Studies major. In addition to normal graduation requirements for all Interdisciplinary Studies majors, students will complete 40 credits for the MRV option.

Background

Mathematics has been part of the IAS curriculum from the beginning and has formed an important part of the campus-level curriculum shared with other programs. Instruction has addressed the applied needs of IAS and other students, especially in statistics, but has also treated mathematics as a subject in its own right, via courses on mathematical aspects of art, game theory, number theory, and other subjects. Within the framework of the IAS learning objectives, a mathematics-centered concentration provides the following opportunities:

Critical Thinking: Mathematics offers tools for logical critique, conceptualizing complex systems, and making data based claims. An understanding of the mathematical forms and assumptions underlying models and data can help make them visible as constructions of knowledge.

Collaboration and Shared Leadership: Accomplishing work in teams requires abilities to communicate and to understand a range of problems that take mathematical forms. [There are a number of position statements from national organizations (such as the Mathematical Association of American, National Science Foundation, etc.) about the need for mathematics to be interdisciplinary. James Keener, a prominent mathematician, says that in the next generation “math graduates will be a) part of a team; b) working on problems that are not well formulated; c) working with people with greatly different training, background, vocabulary, and expectations.” Further, a key writer on mathematical thinking, Keith Devlin states: “To produce the twenty-first century innovative mathematical thinker, you need project-based, group learning in which teams of students are presented with realistic problems that will require mathematical and other kinds of thinking for their solution.”]

Writing and Presentation: Our graduates will be called upon to communicate ideas, results, and analyses that have mathematical forms or properties. This communication will take place through a widening range of media, including photography, film, sound, games, and web interfaces, and many of these media will provide opportunity for richer interaction between the person communicating and the audience.

Interdisciplinary Research: A basic skill is the ability to link up areas of research that use data or mathematical ideas in different ways, including fields of research that make no explicit use of mathematics. Additionally, a number of IAS degrees stress interdisciplinary research that uses and/or creates data.

There are currently three mathematicians on the IAS faculty, and a much larger number of faculty have graduate-level mathematical, statistical, and/or quantitative reasoning. During the 2009-10 academic year IAS made two hires in Geographic Analysis and Visualization, both of whom bring expertise in mathematical modeling, and interpretation of data, as well as experience in communicating the results of geographical work to local communities.

In Spring 2006, John Rasmussen interviewed 15 regional leaders from for- and non-profit organizations. One of his questions asked “What math/quantitative skills and abilities do you value in entry-level college graduates?” Five abilities were identified by more than half of the respondents: (1) translate real world problem into numbers and formulas; (2) use of statistics; (3) understand financial concepts; (4) use Excel; and (5) analyze data and present it visually. All IAS math courses have incorporated these ideas into their learning goals, and IAS developed a new course, BIS232: “Visualizing and Interpreting Data,” as a result of this work. In addition to seeking jobs in organizations such as those interviewed, we anticipate that some of our graduates will use the knowledge from this degree option as data artists. [CH: I’ve emailed a few such artists and will input their feedback here as appropriate]

During Winter 2011, a campus wide “Mathematics and Quantitative Reasoning Task Force” (MQRTF) was established for “cross-program dialogue on best practices in the teaching and learning of mathematics and quantitative reasoning, as well as ways that UW Bothell can meet the needs of a growing campus and increasingly diverse student body.” This task force has inventoried current campus offerings in math and quantitative reasoning as well as reviewed planning documents including the UWB 21st Century Campus Initiative, the Technology and Teaching Innovation Task Force Report, and the Writing and Communication Task Force Report. The MRV degree option is in line with the task force’s discussions that have articulated the need for multiple pathways for students to explore mathematics. This degree can complement a traditional mathematics degree being proposed by the Science and Technology program as multiple courses can be cross-listed for both degrees as faculty development and student support around these issues can be optimized. This degree also provides options for students in the Education program who are seeking to fulfill requirements for their Mathematics Endorsement. At least seven of the IAS courses listed below would meet the requirements for this endorsement [For a complete listing of the Secondary Education Mathematical Endorsement requirements, see: <http://www.uwb.edu/secondarycertmed/mathendorsement>]. Further, conversations have begun with the CSS program, which explores overlaps between the MRV degree and their new curricula in creativity and technology processing.

As IAS grows, we look forward to supporting the growth of mathematics and quantitative reasoning across the campus and contributing to cross-program initiatives, as well as increasing the opportunities of IAS students to learn mathematics and have their work recognized in the form of degrees. In many ways, this degree option can act as a bridge between our degrees and degrees across campus.

Rationale

While there are a number of mathematical degrees that could be built within the IAS program, consultations with faculty inside and outside of IAS lead us to believe that our first emphasis should be in the area of Mathematical Reasoning and Visualization. This degree will build on our strengths in quantitative reasoning, logical and critical thinking, data visualization, and geographic visualization (e.g. GIS). It will support, and develop links to, teaching in Environmental Studies, Environmental Science, Community Psychology, Media and Communication, Policy Studies, Global Studies, Cultural Studies and Interdisciplinary Arts.

While not a standard mathematics degree, the outline of the following degree is broadly in line with a 2010 discussion document of the Mathematical Association of America on what mathematics majors should know [Recommendations from the MAA's Committee on the Undergraduate Program in Mathematics (CUPM) can be found at <http://www.maa.org/cupm/>]. Specifically, they outline seven recommendations for a math degree:

1. All students should achieve mastery of a rich and diverse set of mathematical ideas.
2. All students should be able to think analytically and critically and to formulate problems, solve them, and interpret their solutions.
3. All students should achieve an understanding of the nature of proof.
4. All students should have experience applying knowledge from one branch of mathematics to another and from mathematics to other disciplines.
5. All students should experience mathematics as an engaging field with contemporary open questions as opposed to an elegant body of knowledge that is complete and static.
6. All students majoring in mathematics and mathematics-intensive fields should be able to use a variety of technological tools: e.g., algebraic and visualization software, statistical packages, a high-level programming language.
7. All students should be able to communicate mathematics both orally and in writing.

The IAS curriculum already has strengths in recommendations #2, #4, #5, #6, and #7, and can develop recommendations #1 and #3 by drawing on courses in CUSP, S&T, and developing additional IAS courses.

“Mathematical reasoning” refers to the use of mathematical concepts to reason, in a wide range of areas. It indicates, for example, the abilities to

- recognize mathematical forms in real-world phenomena,
- construct appropriate models (from a range of choices),
- identify and describe key features of the problem mathematically, and use that mathematical description to analyze the problem
- represent relationships in a situation in several different kinds of ways to get different insights including diagrams, graphs, tables, and formulas,
- generate frameworks of concepts that can be filled with data,
- gather data,

- interpret data.

All of these have their critical side: students trained in mathematical reasoning are not compelled to take at face value the models, formulations, or data-derived arguments they encounter. That is, a student with this background should not merely be competent in quantitative reasoning, but able to think critically about the concepts and choices that underlie the frameworks for the data and mathematical models used to address a question. Students should also be able to bring together quantitative and non-quantitative data to address a question.

“Visualization” refers both to ways that we make questions, phenomena, and arguments clear to ourselves, but also ways we communicate them to others. While this degree draws on powerful visual traditions and techniques, it does not preclude sound, narrative, or other technologies of communication. This is a rich area in which work in natural sciences (in particular biology), mapping, social sciences, and arts converge. Some teaching of this kind, as in courses in the Visual Arts in Biology and the mathematics of aesthetics, have already been taught in IAS.

There is already a substantial base of students in several IAS degrees who are taking a required introductory statistics course [For example, the following concentrations require BIS315 (Intro Statistics) for graduation: CP, STS, Env. Science, and SEB. Others, e.g. AMS and ES, also have considerable quantitative tracts.]; a focus in this concentration would let them deepen those skills through advanced courses, explore their theoretical underpinnings, and gain more experience doing research projects that use quantitative methods and communicate results. Courses in logic, mathematical modeling, and visualization, most of which are already being taught regularly in IAS, would round out this option.

There is also a large base of students who are taking required courses in geographic information science (GIS). At both introductory and advanced levels, students are learning a complete new set of quantitative skills within the fields of spatial analysis and geo-visualization. One of the main skills gained through these courses is the ability to translate geographic problems into mathematical and logical formulations that can be used to model, analyze, and quantify the relationships between geographic features and the environment. In addition, the outcomes of these spatial analyses are represented and visualized as a form of map. Students acquire how to create, understand, and interpret geo-visualization where ‘numbers’ and spatial analyses are embedded in its production.

At least a dozen full-time IAS faculty members are potential contributors to a course of study of this kind. Advanced courses in quantitative reasoning would also be attractive to business and science students as well as students in other IAS degrees such as community psychology and policy studies. There are numerous undergraduate and graduate degrees and research centers in quantitative methods and information visualization that we might look to as models [For example, see Columbia’s MA in Quantitative Methods for the Social Sciences (<http://www.columbia.edu/cu/gsas/departments/quantitative-methods-social-sciences/bulletin.html>), or the University of New Hampshire’s Data Visualization Lab (<http://ccom.unh.edu/vislab/index.html>)]. IAS faculty could also contribute significantly to students thinking about knowledge production about and with data, including the ways in which data is created and used.

Developing the above degree would also help IAS meet the growing need for our graduates to achieve competency in quantitative literacy. AAC&U has listed QL as one of its essential learning goals, and there is growing national work that IAS could learn from and contribute to in this area. Throughout IAS, and across the campus, we need to build a culture that sees mathematical methods not as a barrier, or even a hoop to jump through, but a means to insight and better communication. This degree's emphasis on these qualities will serve both its majors and the campus at large.

Learning Objectives

1. Acquire competence in different ways to address real-world problems in mathematical forms.
2. Learn to apply statistical tools and critique their applications, including building and critiquing arguments based on quantitative data. Generate reliable data and evaluate which methods to apply to a given data set.
3. Gain experience creating visual representations of problems and data, and communicate these ideas, results, and analyses in multiple formats.
4. Learn to use mathematical tools across varied disciplinary areas.
5. Learn to work in interdisciplinary teams to communicate and to understand a range of problems that have mathematical underpinnings.

Curriculum

The curriculum of a new Mathematics Reasoning & Visualization degree option will be structured with courses falling into four categories:

1. Prerequisites: Students will be asked to complete

- one quarter of calculus
- one quarter of linear algebra

Students can complete these regularly taught courses at UWB or at another institution. These courses provide underpinnings of the quantitative models and essential mathematical ideas.

2. Required Core Courses: In addition to BIS300 (Introduction to Interdisciplinary Inquiry), which is required of all IAS students, students in this degree would complete

- BIS209 Engaging Visual Arts
- BIS232 Using, Understanding, and Visualizing Quantitative Data
- BIS315 Understanding Statistics.

BIS 209 will introduce students to visual form – to the range of possibilities for visual communication, and the history of visual conventions. Viewers (aside, perhaps, from infants) encounter visual phenomena having already learned to see and interpret them in particular ways. Arts both draw on those learned ways and, sometimes, change them. The course in visual arts, therefore, provides students a richer understanding of the possibilities in visual communication, and a more sophisticated grasp of visual form as a means to communicate, to get something across to an audience.

BIS 232 builds foundational skills in the use of quantitative data. The course introduces students to the scholarship of data visualization. Through multiple case studies, students learn how numbers become proxies for ideas and what information quantitative modeling can and cannot provide for important decision making. Students learn how to locate public data sets and create both a technical and creative presentation from these data sets.

BIS 315 is central to this degree not only for the study of statistical inference, but also because it addresses the fundamental understanding of how data is constructed, and how a given question in the world might be addressed in different ways – different choices of model, different foundational assumptions.

3. Mathematical Concepts and Skills: Students will choose at least three courses that will help them “achieve mastery of a rich and diverse set of mathematical ideas” as recommended by the MAA.

4. Modeling and Visualization in Practice: Students will choose at least two courses that apply mathematical reasoning and visualization to specific problems or research questions.

Like all IAS students, MRV students will take BIS 499, the portfolio capstone.

Category	Credits	Courses
Core	15	BIS 209 Engaging Visual Arts BIS 232 Using, Understanding, and Visualizing Quantitative Data [we may reshape and promote to 300 level] BIS 315 Understanding Statistics
Courses that develop mathematical concepts	15	BCUSP 125/126 Calculus II and III BIS230 Mathematical Thinking for the Liberal Arts BIS302 Issues in Mathematics Across Cultures BIS 329 Topics in Mathematics Across the Curriculum (Topics have included game theory, knot theory, mathematical modeling, symmetry, and cryptography; up to 10 credits) BIS 342 Geographic Information Systems BIS 350 The Concept of Number BISMRV 3xx Logic BISMRV 3xx Graph Theory and Social Decision Making BISMRV 3xx Cryptography BISMRV 4xx Mathematical Systems BISMRV 4xx Combinatorics and Discrete Probability STMATH 300 Foundations of Modern Mathematics STMATH 3xx Mathematical Theory of Games 300-level courses in economic theory 300-level courses in Ecology <i>Selected courses from an upcoming formal math degree in S&T may also be available in this option.</i>
Modeling and Visualization Practice	10	BIS 4XX Geographic Visualization BIS 382 The Visual Art of Biology BIS 434 Psychology and the Visual Arts BIS 447 Topics in Quantitative Inquiry BISMRV 4xx Data Visualization Workshop <i>Suggestions of other IAS and UWB courses are welcome.</i>
Additional IAS Coursework	27	Including 10 IAS credits in each of the UW areas of knowledge, if not already satisfied.
Program Core and Portfolio Capstone	8	BIS300: Interdisciplinary Inquiry BIS 499 Portfolio Capstone
General Electives	20	

Note: Within the 90 credits, students must complete 10 credits each in Individual and Society (I&S), Natural World (NW), and Visual, Literary, and Performing Arts (VLPA).

Faculty and Staff

Alex Barchecheat: Mathematics

Cinnamon Hillyard: Undergraduate Mathematics Education, Numerical Methods for Partial Differential Equations, Ethnomathematics

Jin-Kyu Jung: Geographic Information Science, Urban Geography

Santiago López: Geography and the Environment

John Rasmussen: Interdisciplinary Mathematics, Finance, Computer Modeling

Additional Faculty

Our ability to staff courses, develop curriculum, and work with students would be greatly enhanced by the addition of colleagues in two areas:

Statistics and modeling: A social or natural scientist with experience designing and applying a range of models and statistical techniques

Visualization: A scholar with training in both mathematics and visual arts

While not essential to begin the degree, a colleague who could teach logic would help expand options to students in the degree.

Administration and Advising

The MRV option will be housed and administered in the IAS program under the leadership of the IAS program director. Advising will be done principally by IAS advisors, as is done for other IAS options and degrees.

Effect on Curriculum

The most significant positive effect of a new MRV option on the rest of the IAS curriculum, apart from the increase in enrollments and economies of scale within IAS and UWB, will be to provide an increased level of proficiency in mathematical reasoning, quantitative literacy, data visualization and communication across the program and campus. We anticipate that this increased quantitative literacy among students will strengthen courses throughout the program and across the campus.

The most significant negative effect will be to draw faculty teaching away from other options in which those faculty currently teach. This concern is addressed in part by the request for faculty to both develop new courses within the MRV option and to help cover existing courses in other options for which existing faculty will no longer be available.

At the moment, the prerequisites for this degree are being taught on a regular basis, as are BIS 315 and BIS 209. BIS 232 (Using, Understanding, and Visualizing Quantitative Data) is not taught frequently, and would assume a key role in this degree (we may also want to promote it to the 300 level), so that we will at a minimum need to free up faculty time to develop and teach this course. Among the upper-level electives, we offer enough at the moment that a student could fulfill requirements, but choices would not be large. A particular need would be for a regularly-offered logic course. More hiring and freeing-up of the time of colleagues will be necessary to launch this degree.

Budgetary Impact

Discussion of

- library resources
- quantitative skills and overall teaching and learning center resources
- learning technologies, computing, and software

Bachelor of Science in Mathematics (S&T)

Proposal for a Bachelor of Science in Mathematics

Science and Technology

University of Washington Bothell

Proposed Start Date: Fall 2012

Note: This document represents a starting point for this proposal development. If the S&T Program supports it, it can be anticipated to evolve as it progresses toward a formal proposal to be sent beyond the S&T Program.

Overview and Rationale for S&T Evaluation of Proposal

We propose a Bachelor of Science degree in Mathematics with two options: Standard and Teacher Preparation

a. *What is the relationship of this curricular proposal to the strategic plan, goals and objectives of the S&T Program? (Interpreted very broadly.)*

The BS in Mathematics will begin to establish mathematics as an important component of the S&T curriculum and mission. It should help S&T, and UWB, to present itself as a STEM school of choice to prospective students by making explicit an option in a central area that is served by all peer institutions. More specifically, the degree speaks to the following statements in the S&T Mission:

Create STEM (as supported by the National Science Foundation) degrees that are recognizable and address the needs of high school students, parents, employers, and graduate/professional schools.

Provide degrees that will prepare students to become math and science educators and support P-12 outreach projects.

b. *What groups of students will take this curricular offering and what will the degree accomplish for these students?*

We believe that a BS in Mathematics will be attractive to students desiring a career in teaching mathematics as well as students who want a second major to have a “value added” credential to their record. For students in science and engineering areas, a BS in Mathematics will convey those students’ interest and skills in the underlying foundational aspects and tools of their discipline. It is thought that many employers value mathematical skills, which are often associated with other technical skills. Mathematically trained people are often considered to be valuable as employees who can bring the ability to analyze and solve problems of a quantitative nature. Having a BS in Mathematics can give student a competitive edge for admission to a range of graduate school programs.

Examples of student who may double major include:

i. Electrical Engineering majors. Presently a number of these students are taking the math minor offered by UWS. Some of these students may choose to either minor or major in Mathematics if such a degree exists at UWB. It is estimated that at least 10-12 EE majors will be Math Minors or Majors each year.

ii. Climate Science majors in the modeling intensive track. Some climate science students may be interested in graduate school in atmospheric chemistry or related fields. This math credential will give them a perceived advantage in the admission process. There could be several students each year (3-5) at program maturity.

iii. CSS majors. There could be potentially 2-3 students per year.

iv. Prospective physics, and chemistry majors. Presently, students interested in majoring in these areas must plan on transferring as juniors to another campus or university. The math minor or major may well be perceived as increasing their admissibility to these institutions. If they transfer to UWS, it will eventually be transcribed. We estimate that there could be as many five of these students each year.

c. What is the anticipated demand for this curriculum? What data is available to support this expectation?

We estimate that there will be approximately 15-25 students per year at program maturity.

Proposed Curriculum

While the proposed curriculum represents a standard mathematics degree, the required courses reflect the recommendations put forth by the Mathematical Association of America's (MAA) CUPM Curriculum Guide 2004 for majors preparing to be secondary mathematics teachers. According to MAA, mathematical sciences majors preparing to teach secondary mathematics should:

- Learn to make appropriate connections between the advanced mathematics they are learning and the secondary mathematics they will be teaching. They should be helped to reach this understanding in courses throughout the curriculum and through a senior-level experience that makes these connections explicit.
- Fulfill the requirements for a mathematics major by including topics from abstract algebra and number theory, analysis (advanced calculus or real analysis), discrete mathematics, geometry, and statistics and probability with an emphasis on data analysis;
- Learn about the history of mathematics and its applications, including recent work;
- Experience many forms of mathematical modeling and a variety of technological tools, including graphing calculators and geometry software.

The proposed **Bachelor of Science in Mathematics** requires completion of 72-82 credits with minimum average GPA of 2.5, distributed as follows:

Mathematics Basic Core Requirement (40 credits)

- STMATH 124, 125, 126 Calculus (15)
- STMATH 324 Multivariable Calculus I (5)
- STMATH 307 Differential Equations (5)

- STMATH 308 Matrix Algebra (5)
- STMATH 300 Foundations of Modern Mathematics (5)
- One of: STMATH 311 Elements of Statistical Methods (5), STMATH 390 Probability and Statistics in Engineering and Science (5)

Mathematics Advanced Core Requirement (12-20 credits)

Teaching Preparation Option

- STMATH 411 Modern Algebra for Teachers (3-5)
- STMATH 420 History of Mathematics (3-5)
- STMATH 421 Conceptual Calculus for Teachers (3-5)
- STMATH 444 Geometry for Teachers (3-5)

Standard Option

- STMATH 326 Multivariable Calculus II (3)
- STMATH 402 Abstract Algebra (3-5)
- One of: STMATH 424 Real Analysis, STMATH 427 Complex Variables; (3)

Mathematics Elective Requirement (10-12 credits; 300-level or above)

- STMATH 301 Elementary Number Theory (3)
- STMATH 326 Multivariable Calculus II (3)
- STMATH 381 Discrete Mathematical Modeling (3)
- One of: BST 293 Cryptography (5), BST 293 Game Theory (5)
- STMATH 402 Abstract Algebra (3-5)
- STMATH 411 Modern Algebra for Teachers (3-5)
- STMATH 420 History of Mathematics (3-5)
- STMATH 421 Conceptual Calculus for Teachers (3-5)
- STMATH 424 Real Analysis (3)
- STMATH 427 Complex Variables; (3)
- STMATH 444 Geometry for Teachers (3-5)

Note: It is expected that the elective course list would evolve with experience and curricular growth. The general guideline would be that most electives would depend upon Calc II as a prerequisite. Some exceptions may occur, and that is the reason that students may only choose one of either Game Theory or Cryptography.

Required Supportive Courses (10 credits)

- CSS 161 Fundamentals of Computing (5)
- B CUSP 149 Mechanics (5)

d. Regarding course impact, what new courses will be needed? Who will be available to teach them? Will existing courses have capacity for any additional students?

Existing Courses: Most of the curriculum is already being offered or we have committed to offer them to support our electrical engineering major. The entire core curriculum must already be offered every year. No new sections would be required. Because the elective course list is larger than the number of required credits, not every course need be offered every year. Mathematical Game theory and Cryptography are not required by EE, but are courses that have been taught in the past. We anticipate them being continued on at least a semi-regular basis. The major may help populate these courses.

New Courses: While there are many new courses proposed for this degree, many are electives and can be run on a rotating basis. We have several faculty in S&T (as well as in other UWB programs) who can provide support for the development and teaching of these courses: Peter Littig, Linda Simonsen, Andrew Abian, Eric Salathe, Roberto Altschul, and Kim Gunnerson. It is predicted that future hires will be needed as this program matures.

Minor in Mathematics (S&T)

Proposal for a Minor in Mathematics

Science and Technology

University of Washington Bothell

Proposed Start Date: Fall 2012

Note: This document represents a starting point for this proposal development. If the S&T Program supports it, it can be anticipated to evolve as it progresses toward a formal proposal to be sent beyond the S&T Program.

Overview and Rationale for S&T Evaluation of Proposal

We propose a Minor in Mathematics.

a. *What is the relationship of this curricular proposal to the strategic plan, goals and objectives of the S&T Program? (Interpreted very broadly.)*

The Minor in Mathematics will begin to establish mathematics as an important component of the S&T curriculum and mission. It will anticipate the possible development of a mathematics or mathematics-related major. It should help S&T to present itself as a STEM school of choice to prospective students by making explicit an option in a central area that is served by all peer institutions. More specifically, the degree speaks to the following statement in the S&T Mission:

Create STEM (as supported by the National Science Foundation) degrees that are recognizable and address the needs of high school students, parents, employers, and graduate/professional schools.

b. *What groups of students will take this curricular offering and what will the degree accomplish for these students?*

We believe that a minor is most attractive to students if it can be achieved with modest effort beyond their major and provides a “value added” credential to their record. For students in science and engineering areas, a minor in mathematics will convey that student interest and skills in the underlying foundational aspects and tools of their discipline. It is thought that many employers value mathematical skills, which are often associated with other technical skills. Mathematically trained people are often considered to be valuable as employees who can bring the ability to analyze and solve problems of a quantitative nature. Having a minor in mathematics can give students a competitive edge for admission to a range of graduate school programs.

Examples of student who may double major include:

i. Electrical Engineering majors. Initially, this will be our largest group of students. They will be able to earn the minor by taking only one additional course beyond the mathematics expected of them as EE majors. Presently a number of these students are taking the math minor offered by UWS. Some of these students may choose to either minor or major in Mathematics if such a degree exists at UWB. The

UWB minor will be more convenient for them. It is estimated that at least 10-12 EE majors will be Math Minors or Majors each year.

ii. Climate Science majors in the modeling intensive track will the minor to be attractive, as it may require as few as three additional courses beyond what they will be advised to take. Some climate science students may be interested in graduate school in atmospheric chemistry or related fields. This math credential will give them a perceived advantage in the admission process. There could be several students each year (3-5) at program maturity.

iii. CSS majors. Some CSS majors have quite strong math backgrounds and would only need approximately three additional mathematics courses. They often take three calculus courses, linear algebra and a statistics course. There could be potentially 2-3 students per year.

iv. Prospective math, applied math, physics, and chemistry majors. Presently, students interested in majoring in these areas must plan on transferring as juniors to another campus or university. The math minor may well be perceived as increasing their admissibility to these institutions. With a well directed effort and perhaps some advanced placement credit, the minor can be achieved within two years. If they transfer to UWS, it will eventually be transcribed. If they transfer to another institution, they will not receive the minor, but will have a significant amount of math preparation on their record. We estimate that there could be as many five of these students each year.

c. What is the anticipated demand for this curriculum? What data is available to support this expectation?

We estimate that there will be approximately 15-25 students per year at program maturity, each taking 1-3 extra courses

d. Regarding course impact, what new courses will be needed? Who will be available to teach them? Will existing courses have capacity for any additional students?

Existing Courses: Most of the curriculum is already being offered or we have committed to offer them to support our electrical engineering major. We do anticipate that any of these will be over subscribed in the near future. The entire core curriculum must already be offered every year. No new sections would be required. Because the elective course list is larger than the number of required credits, not every course need be offered every year. Mathematical Game theory and Cryptography are not required by EE, but are courses that have been taught in the past. We anticipate them being continued on at least a semi-regular basis. The minor may help populate these courses.

New Courses: No new courses are needed for the minor in mathematics.

Proposed Curriculum

While the proposed curriculum represents a standard minor in mathematics similar to the mathematics minor that many of our students are completing via UWS.

The proposed **Minor in Mathematics** requires completion of 32-35 credits with minimum average GPA of 2.0, distributed as follows:

Mathematics Basic Core Requirement (15 credits)

- STMATH 125, 126 Calculus (10)
- STMATH 308 Matrix Algebra (5)

Mathematics Elective Requirement (17-20 credits; 300-level or above)

- STMATH 300 Foundations of Modern Mathematics (5)
- STMATH 301 Elementary Number Theory (3)
- STMATH 307 Differential Equations (5)
- STMATH 324 Multivariable Calculus I (5)
- STMATH 390 Probability and Statistics in Engineering and Science (5)
- CSS 343 Data Structures and Algorithms (5)
- One of: BST 293 Cryptography (5), BST 293 Game Theory (5)

Note: It is expected that the elective course list would evolve with experience and curricular growth. The general guideline would be that most electives would depend upon Calc II as a prerequisite. Some exceptions may occur, and that is the reason that students may only choose one of either Game Theory or Cryptography.