Creating Interdisciplinary Research Pathways for Early STEM Students

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Introduction

Undergraduate research experiences engage students in a unique combination of activities to achieve diverse cognitive and behavioral outcomes [1,2,3]. Participation:

- advances student learning [4,5]
- increases the likelihood of earning a degree [6]
- retains diverse students in fields in which they are traditionally underrepresented [6].

Course-based undergraduate research experiences (CUREs) are high-impact strategies that expose more students to the benefits of participating in authentic scientific practice [7, 8, 9] and o accomplishes this early in the postsecondary curriculum [10].

Additionally, research shows that microcommunities of peer-to-peer relationships and faculty mentors, common in undergraduate research programs, support underrepresented students' long-term success in STEM [11, 12]. These relationships foster the development of a STEM identity, ultimately allowing students to see themselves as able to make meaningful contributions to their disciplines.

The undergraduate research program at North Seattle College (NSC) has evolved from a grassroots effort with a few students to a two-phase multi-year program that engages hundreds of students at various levels of research activities [13]. UREs at NSC are currently offered in a variety of formats all of which are linked together to create structured research pathways (Figure 1).

Figure 1: The Research Pathway at North Seattle College. Embedded CUREs in gateway Chemistry and Biology courses engage students in authentic research, preparing them for a second-year, skills focused extensive research experience.

Two primary research questions guide our URE design:

1. *How can we design curriculum to nurture both investigative dispositions interdisciplinary integration as a means to engage students in complex thinking early in the STEM pathway?*
2. *What do students gain in both the cognitive and affective dimensions of learning as a result of engaging in interdisciplinary investigative learning environments?*

Design Approach

Curriculum for CUREs and UREs

- Process: Iteratively design and redesign CUREs and UREs based on the collection and analysis of student work, student reflections, and student observations (Figure 2)[14].

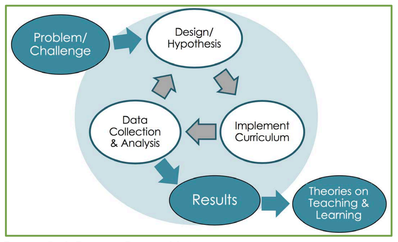


Figure 2: A Design-Based Methodology.

- Partnerships: cross-institution and interdisciplinary collaborations brings a current and established scientific research context to STEM courses at a two-year college.
- Framework: interdisciplinary [15], visible[16] and investigative [17] thinking as provocation for curriculum design in both CURES and UREs (Figure 3).

Figure 3: Theoretical Inspiration. Curriculum design was influenced by leading scholars in interdisciplinary, visible, and investigative thinking.

CUREs in Gateway Chemistry and Biology Courses

The path to engaging and retaining a diverse array of STEM students at NSC begins with embedded CUREs in gateway STEM courses including general chemistry and biology:

First Year Course-Based Research Experiences

Interdisciplinary Investigations: IDI-Classroom

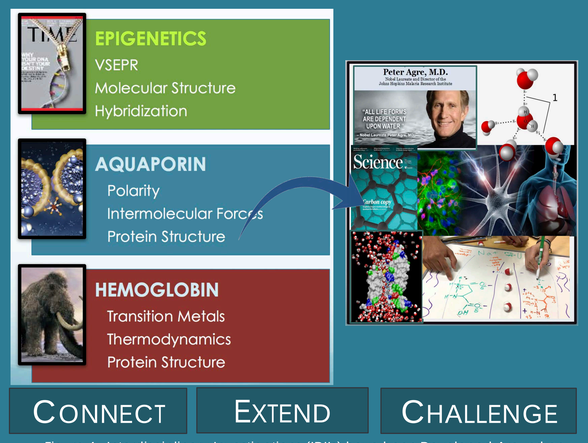


Figure 4: Interdisciplinary Investigations (IDI's) have been Developed Around on Aquaporin, Epigenetics, and Hemoglobin.

The IDI-Classroom curriculum provides structured interventions in the classroom that complements the IDI-Lab modules and is designed around essential principles:

- Provocation (Figure 4)
- Social-Mediated Construction of Knowledge (Figure 5)
- Representation
- Documentation and Metacognition

Figure 5: Interdisciplinary Investigations (IDI's) Require Co-Construction to Address Complex Interdisciplinary Challenges.

Interdisciplinary Investigation: IDI-Lab

IDI-Labs highlight a single, core research-grade instrument (Figure 6). Students build skills across the three-quarter experience (Figure 7). In general chemistry, for example, students replace two labs with an exploration of fluoride in water where they learn how to access primary literature and ion chromatography (IC). In their second quarter, students generate a question about eutrophication, design their protocol, and analyze samples. The third quarter culminates with a 5-6 week project where students iteratively collect and analyze samples, and present at a college-wide symposium.

Figure 6: NSC's Program uses IIC in General Chemistry and a LI-COR 6800 in General Biology.

In general biology, students progress through a similar set of exercises culminating in a student-designed, multiweek investigation into soil respiration presented at the college symposium.

Figure 7: Progression of Research Experience in General Chemistry.

Second Year Research Experiences

Student-Driven Undergraduate Research: Year-long URE

Second year students can choose to take a 3-quarter undergraduate research experience by enrolling in a team-taught, skills-focused series of courses designed around core principles (Figure 8).

Figure 8: Second-Year Students Conduct Authentic, Student-Driven Research in a Program Designed Around Core Principles.

Students spend their first quarter conducting a small-scale, scaffolded project and building essential skills including:

- Finding and reading primary literature
- Developing a research question
- Immersion in STEM culture

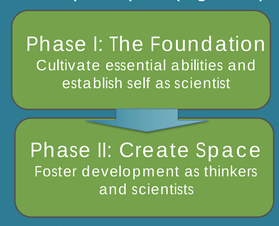


Figure 9: The Year-Long Research Experience.

In the second and third quarters, students transition to collaboratively developing their own research proposals and conducting the research. A scaffolded set of classroom activities allows students to iteratively develop essential skills and evaluate their progress on a series of detailed rubrics. The experience culminates in a poster presented at the University of Washington (UW) Undergraduate Research Symposium (Figure 10).

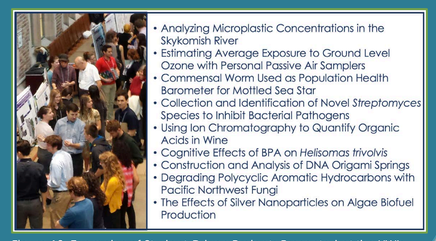


Figure 10: Examples of Student-Driven Projects Presented at the UW's Undergraduate Research Symposium.

Student Learning

Capturing Interdisciplinary Thinking

Drawing to Learn: Pre/post drawings capture student thinking and learning in an interdisciplinary context (Figure 11). The Boix-Mansilla Framework is used for coding [14].

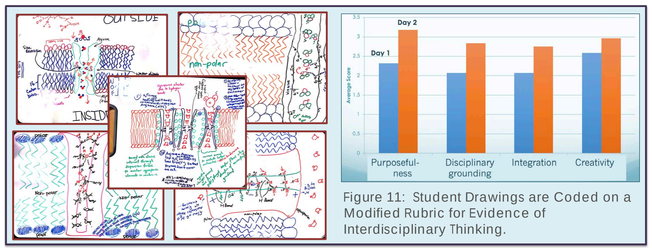


Figure 11: Student Drawings are Coded on a Modified Rubric for Evidence of Interdisciplinary Thinking.

Student Perceptions and Reflections

Student Reflections: Students reflect on their own progress on detailed rubrics and standardized surveys (Figure 12) [15].

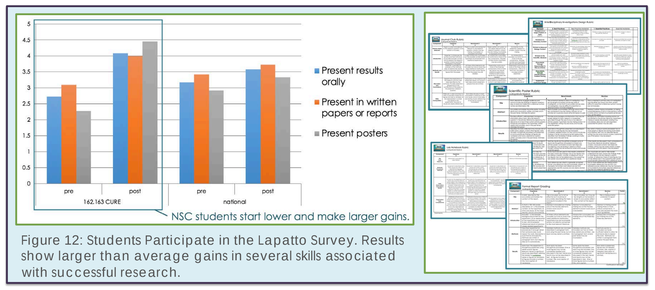
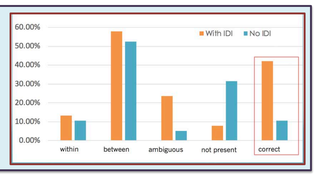


Figure 12: Students Participate in the Lapatto Survey. Results show larger than average gains in several skills associated with successful research.

Concept Mastery

Student Learning Gains: Embedded assessments of threshold concepts such as hydrogen bonding show strong improvement in students participating in IDI's (Figure 13) [16].

Figure 13: Percentage of Students Correctly Drawing Hydrogen Bonds between Methanol Molecule Improves After Participation in an IDI. After participating in a general chemistry course with IDIs, 42% of students correctly drew hydrogen bonds between ethanol molecules compared to a national average of 15%.



Metacognition

Video Captures: A video capture method is used to capture student learning in an interdisciplinary environment. The video is then broken down into a series of stills to be shared with students, instructors, and departments (Figure 14).

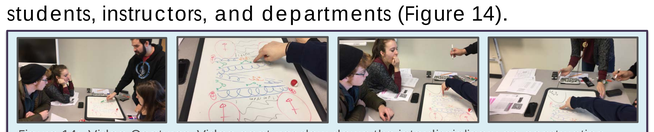


Figure 14: Video Captures. Video captures slow down the interdisciplinary co-construction that occurs during an IDI providing a tool for faculty, researchers, and students to better understand the learning that occurs in this setting.

Final Thoughts

- *Interdisciplinary, Investigative, Inclusive, Innovative curriculum* transforms STEM gateway courses to achieve more with our students, to drive a cultural shift, and to move closer to an equitable experience for all students.
- Early research opportunities are evolving at community colleges—research is needed to determine best practices.

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