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Awareness, Analysis, and Action: Curricular Alignment for Student Success in General Chemistry

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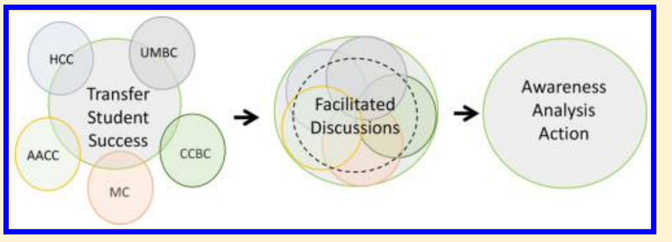

ABSTRACT: This article examines the ways that a shared faculty experience across five partner institutions led to a deep awareness of the curriculum and pedagogy of general chemistry coursework, and ultimately, to a collaborative action plan for student success. The team identified key differences and similarities in course content and instructional experiences. The comparative analysis yielded many more similarities than differences, and therefore, the team shifted its focus from "gap analysis" to an exploration of common curricular challenges. To address these challenges, the team developed content for targeted instructional resources that promoted the success of all STEM students across institutions. This article contextualizes the interinstitutional collaboration and closely examines the interactive components (awareness, analysis, and action), critical tools, and productive attitudes that undergirded the curricular alignment process of the STEM Transfer Student Success Initiative (t-STEM).

KEYWORDS: *First-Year Undergraduate/General, Curriculum, Testing/Assessment, Standards National/State*

INTRODUCTION

The twin agendas of increasing college completion and developing STEM competencies for a growing marketplace prompted a new urgency in higher education.[1] In addressing these goals and a host of other educational issues, the role of students who transition from community colleges to universities has become more visible.[2−4] More than 40% of undergraduate students in the nation start their trajectory in higher education at a community college.[5] These students merit the same kind of focused attention as students who enter the university directly from high school.

Faculty play a critical role in this work.[6−10] Due to the pace of the semester, it can be a challenge for faculty to carve out time to meet with colleagues in their own department.[11] The challenge is increased if these colleagues are situated on multiple campuses or affiliated with different institutions. Despite the difficulty, a shared commitment to student success motivated 12 chemistry faculty members from five institutions that were part of the STEM Transfer Student Success Initiative (t-STEM) to work together, and figure out how best to bolster that success. This structured interinstitutional opportunity for faculty collaboration generated shared professional knowledge that, in turn, helped to support student learning in and out of the classroom. This generative process represented an important component of t-STEM's more comprehensive approach to transfer student success that engaged over 100 faculty and staff across the partner institutions of Anne Arundel Community College (AACC), The Community College of Baltimore County (CCBC), Howard Community College (HCC), Montgomery College (MC), and the University of Maryland, Baltimore County (UMBC).

This shared faculty experience was initially informed by the *Significant Discussions* publication.[12] The faculty team identified key similarities and differences in general chemistry course content and instructional practice. Though laboratory components were addressed, the focus was largely on the classroom experience. Because the comparative analysis yielded many more similarities than differences, the team shifted its focus from "gap analysis"[12] to an exploration of common curricular challenges. To address these challenges, the team developed an action plan that mapped out the content for needed instructional resources. The purpose of these targeted resources

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was to promote the success of all STEM students *across* institutions. This article contextualizes the interinstitutional collaboration and closely examines the interactive components (awareness, analysis, and action), critical tools, and productive attitudes that undergirded the t-STEM curricular alignment process.

This work responds to Wesemann's[10] call for the "chemistry community to support and encourage local, regional and national efforts to facilitate undergraduate transitions across institutions", and thereby widen participation in and understanding of the sciences (p 197). Toward this end, the work of the t-STEM chemistry team complements the achievements of other interinstitution teams, such as the development of undergraduate student and faculty research collaborations, and the successful integration of nuclear magnetic resonance (NMR) spectroscopy across the chemistry curriculum.[6,9] The t-STEM chemistry team provided a distinctive contribution in the way that it developed a tool-driven process for curricular investigations that reached beyond the traditional boundaries of articulation and alignment. In this way, they created a new analytic space for shared inquiry into curricula and collaboration around student learning. As Rhodes et al. assert (ref 7, p 9):

> *If student learning is to be central to student transfer—to address the needs and discover the talents of twenty-first century learners—we need to envision a central role for faculty who teach as well as faculty who design the curriculum and its components. If higher education is to transition to a proficiency-based model—in transitional, virtual, and hybrid classroom settings—faculty will need to collaborate across institutions and states to do the work. They will need to create new ways of working together, in sum, for larger educational progress.*

The endeavors of the t-STEM chemistry faculty aptly illustrate these kinds of efforts and offer a national model of collaboration for STEM student success. The focused attention on faculty practices may help other two-year and four-year teams to establish or enhance their own collaborative work, particularly in the field of chemistry.

■ ROLE OF THE T-STEM CURRICULAR ALIGNMENT TEAM IN CHEMISTRY

Chemistry emerged as the best choice for t-STEM's first pilot in curricular alignment for three main reasons. First, the American Chemical Society (ACS) has accreditation guidelines for bachelor's degree programs that are recognized by most chemistry departments in higher education. These guidelines define and standardize key competencies. Second, a general chemistry sequence is required for many STEM majors; thus, any curricular efforts had the potential for wide impact. Third, one of us (W.R.L.), the dean of natural sciences and mathematics at the University of Maryland, Baltimore County, was an early advocate for the collaboration, as well as a co-PI for the second grant that funded t-STEM. As a chemist, a chemistry educator, and a transfer student from a two-year college, the insight and leadership of W.R.L. were important for the curricular alignment process.

After the disciplinary field was identified, administrators across institutions worked together to launch the curricular alignment process. Recognizing the importance of creating a productive context for this process,[7,12−14] the administrators carefully identified faculty at each institution for the alignment team. A participating community college dean (identified here as PT)[15] developed a comprehensive list of possible selection criteria, such as an understanding of the value of interinstitutional collaboration and a working knowledge of the curricula. To generate greater investment from faculty, PT also asserted that administrators should help curricular alignment team members adjust their workloads, and incorporate this work into promotion plans or annual plans. Additionally, PT explained that administrators should publicly recognize the efforts of curricular alignment team members, provide support services and facilities as needed, and make a commitment to assist in the implementation of any course or program recommendations.[15]

In t-STEM, the administrators selected open-minded and capable team members for this curricular effort across the institutions. New members replaced faculty who retired or changed positions, yet the original team membership stayed relatively stable over time. The university dean (W.R.L.) or assistant dean (K.S.) served as the facilitator during the meetings, striving to advance the alignment work and ensure equitable participation among the team members.[12] To engage everyone in early alignment team activities, the schedule often included dual, identical monthly meetings. Team members made a concerted effort to meet face-to-face, yet sometimes online and telephone options enabled greater participation for any given meeting.

To help create a shared context and common goal for the team at the onset of the t-STEM Initiative, W.R.L. shared longitudinal course data for chemistry. These data showed the academic vulnerability of students who transferred as compared to students who entered directly from high school. Table 1 provides UMBC institutional comparative data of the Drop/Fail/Withdraw rates (DFW) in chemistry courses for full-time freshmen (FTF) and transfer students from Fall 2009 to Spring 2011 (see Table 1).

Table 1. DFW Percentage Summary of Chemistry Courses from Fall 2009 to Spring 2011

Course (Semester in Sequence)	Students Receiving a grade of D, F, or Withdrawing (Not Passing)	
	Full-Time Freshmen, %	Transfer Students, %
CHEM 101 (General I)	18.3	38.9
CHEM 102 (General II)	20.7	44.9
CHEM 351 (Organic I)	36.0	53.0

These data were even more compelling in the context of national discussions around retention and degree completion among STEM undergraduates.[1,3] Out of these data-driven discussions, the team acknowledged the need for academic improvement among students from all partner institutions, and chose to focus its work on the general chemistry sequence. Not only was the coursework required for many STEM majors, it preceded a two-semester sophomore sequence in organic chemistry for all partner institutions. As the process evolved, the team focused on the content mastery needed for the successful transition between the first and second semesters of general chemistry.

There was some initial concern from the community college faculty that this process would serve as an opportunity for the university to dictate change at the community colleges. However, focusing on student success, foregrounding data analysis, and engaging in honest discussions helped to change those perceptions.[16] Also, the larger and explicit t-STEM

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commitment to an asset-based perspective on transfer helped to build a positive ethos.[17] In this way, the team tapped its strengths and worked against deficit perspectives on transfer[18] and narratives of interinstitutional disrespect or contention.[8,19] Alignment, *not blame*, was the focus of all discussions.

Built on this framework, the team became a vital community of professional colleagues engaged in the important work of curricular alignment. Through this process, the team focused on generating awareness, analysis, and action. Though examined individually in subsequent sections, it is important to recognize that these steps are not isolated, but intertwined and interdependent. As a vital component of the process, the team adapted, developed, and utilized inventory and analytic tools. The use of tools, and the subsequent data analysis, undergirded the work and helped the faculty to create relevant instructional resources. All tools will be posted online[20] for use and adaptation by interested partner institutions. Selected instructional resources are posted on the site under the header "STEM Competencies".[20]

CURRICULUM ALIGNMENT

Curricular Awareness: Using Inventory Tools To Document Practices

The first task of the chemistry team was to determine the interinstitutional range and variation of curricular, pedagogical, and assessment practices across general chemistry courses. The team developed, refined, and utilized three inventory-based tools for collecting and documenting course-related information (see Table 2).

Table 2. Inventory-Based Tools for Curricular Alignment

Tool	Inventory	Description
1	Course Topics	Multiple worksheets listing categories/topics of instruction in the introductory course sequence (with the degree of emphases of coverage on each).
2	Pedagogy and Resources	Single worksheet listing a range of questions grouped in categories that focused on the pedagogy of and resources for the targeted introductory courses.
3	Assessment	Single worksheet listing a variety of questions with categories of assessment that focused on the targeted introductory courses.

For each tool, team members carefully included inventory items that would ensure both breadth and depth in their course investigations. Then, they took each blank tool matrix to their home institution to gather information from colleagues within their departments. As evidenced in Table 2, as well as in the forthcoming descriptions, these tools went well beyond the syllabi topics central to most articulation processes. Though the tools have been subsequently streamlined to be more helpful to emergent partnerships, all descriptions reference the original tools used by the team.

Tool 1 (Course Topics) included general information such as course numbers, credits, class sizes, prerequisites, textbooks, and math competency expectations, yet central to its purpose, it listed 21 major topic categories, each further divided into subcategories. This survey tool had three separate subsurvey sheets. The first and second subsurvey sheets focused on the topic coverage in the first and second semester of general chemistry courses, respectively. The third subsurvey sheet focused on the general chemistry topics most important for retention in the first semester of organic chemistry. Each institution indicated the average level of coverage and scored the level of needed retention. For example, the team identified the topics related to gases, and each team member documented typical results from his or her own individual institution. Recognizing the possibility of instructor variance, Table 3 represents the compilation of responses across institutions with regard to the coverage of gases (see Table 3). Through the chart, the information about gases was easily compared. It showed great similarity except for one notable exception.

Table 3. Comparison of Coverage of Gases at Partner Institutions During the First Semester

	Extent of Topic Coverage by Institutional Partners[a]				
Subtopics of Category 5: Gases	A	B	C	D	E
Properties of gases (compared to solids and liquids)	2	3	2	3	0
Pressure of gases (measurement, units)	3	3	3	3	0
Gas laws	3	3	3	3	0
Ideal gas equation	3	3	3	3	0
Dalton's law of partial pressures	3	3	3	3	0
Kinetic molecular theory	2	3	3	3	0
Deviation from ideal behavior	1	3	1	2	0
Stoichiometry calculations involving gases	2	3	3	3	0

[a]None = 0. Light = 1. Moderate = 2. Heavy = 3.

The exception highlighted the critical importance of collegial discussion about data. The information in the table *could* have indicated that Institution E, the exception, did not cover gases. Through discussion; however, the team discovered that Institution E covered gases, but not in the first course of the general chemistry sequence. While all institutions covered similar information in the overall two-semester course sequence, the distribution of the content between the two semesters differed for the institutions. Therefore, if a student transferred between the two introductory courses, the difference in coverage could negatively affect the student's exposure to content. Rather than pressure institutions to change content coverage, a practice that ran against the principles of the t-STEM effort, the team recommended that advisors encourage students to take both semesters of the two-course chemistry sequence at the same institution to avoid potential gaps in coverage. This advice was posted on the t-STEM Web site[20] to help transfer students and their advisors plan for a successful transition, and it was also disseminated in other appropriate venues. Discussions of coverage also illuminated areas of high student interest. For example, colleagues teaching nuclear chemistry reported that student interest in this topic was consistently high. As a way to spark enthusiasm for the study of chemistry, individual team members who had not emphasized nuclear chemistry expanded their coverage of it. These examples provide apt illustrations of the specificity of the discussions and the interactive nature of the curricular alignment process. Awareness, analysis, and action work together, and do not function independently of each other.

The team used the other inventory-based tools in a similar fashion. In Tool 2 (Pedagogy and Resources), the team explored the various resources available to instructors and students at each institution. In this case, the team grouped 152 items related to pedagogical platforms, resources, and types of support available to teachers and/or students into five major categories. Similarly, in Tool 3 (Assessment), the team grouped 109 items into 13 categories. The tool focused on all aspects of

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Table 4. Analytic Tools for Curricular Alignment

Tool	Inventory	Description
4	Difference Identification and Recommendations	A one-page document with recommendations given in two tables: Table 1 focused on gaps/differences in General Chemistry I & II course alignment. Table 2 focused on tasks and implementation strategies.
5	Skill and Concept Inventory in Foundational Instruction (SCI-FI)	A table with the identified skills and concepts critical to success in introductory chemistry as agreed upon by the entire team: the five SCI-FI categories focused on: (i) preparatory skills; (ii) preparatory concept knowledge; (iii) skills that students have difficulty mastering; (iv) concepts that students have difficulty understanding; and (v) key concepts that require repeated reintroduction in the chemistry course sequence.

Table 5. Preparation and Mastery Responses Excerpted from the Skill and Concept Inventory in Foundational Instruction

Skills and Concepts	Questions Eliciting Skills and Concepts Critical to Success in Introductory Chemistry	Common Responses among Team Members of Partner Institutions
Preparation Skills	What preparatory skills would benefit your incoming students?	Use of scientific calculators (log, ln, antilog, antiln, exponents, etc.)
		Use and interpretation of graphs
		Algebra skills to (a) solve for an unknown in both linear and quadratic equations, and (b) rearrange equations
		Use of units and scientific notation
		Study skills and time management
Preparation Concepts	What preparatory concept knowledge would benefit your incoming students?	Recall of content from CHEM 101 (first-semester general chemistry) when beginning CHEM 102 (second-semester general chemistry)
Mastery Skills	What skills do your students in introductory chemistry generally have trouble mastering?	Problem-solving, including word problems, problems out-of-context, multidimensional problems, problems using previously learned "old" material
		Use of units and significant figures
		Dimensional analysis
		Basic mathematical manipulations (on paper and using a calculator)
		Using Lewis structures to determine molecular shape and polarity from a formula
		Recognizing ionic and molecular compounds from formulas
Mastery Concepts	What concepts do students in introductory chemistry generally have problems understanding?	Identifying electrolytes and using that information to write net ionic equations, and understanding how that affects colligative properties
	What key concepts do you have to repeatedly introduce to your students taking the sequence of introductory chemistry courses?	Acids and bases (strong versus weak) and especially their use in titrations and buffers

student assessment, such as quizzes, tests, final exams, classwork, homework, and laboratories, and also provided brief descriptions about grading practices and philosophies. For Tools 2 and 3, each institution indicated the average level of use, importance, or availability of each item using a scale ranging from 0 (minimum score) to 4 (maximum score). Each tool had a column for notes that provided space for particular explanations or contexts. If needed, the team also had the option to record great variances between instructors, classrooms, or campuses.

The process of completing each of the inventory-based tools typically extended over many weeks and across several meetings. Over time, this process prompted many important discussions about individual and institutional practices, and provided opportunities for collegial exchanges about best practices. This teamwork greatly increased their level of curricular awareness, and provided the information needed for the subsequent analytic work.

Curricular Analysis: Using Analytic Tools To Summarize Key Trends

Using the compiled and archived inventory tools, the team engaged in a systematic analysis of their findings from Tools 1, 2, and 3. As evidenced in the previous section, each institution's information was coded for easy reference and comparison. At each meeting, the team focused on a particular tool, and looked closely at the completed matrices to determine preliminary similarities and differences across institutions. Even with the noted similarities, each of the inventory tools yielded important information, and led to important lessons learned. These lessons were summarized in analytic Tools 4 and 5 (see Tables 4 and 5). This section highlights the analytic work and introduces these additional tools.

As expected, due in large part to the influence of ACS accreditation requirements, the analysis of Tool 1 (Content) indicated that the topics covered and the amount of coverage across institutions were very similar in the general chemistry sequence. In particular, the team discovered that more than three-quarters of the responses for almost all categories indicated that the partner institutions provided moderate to extensive coverage of the content required for first semester general chemistry. From the analysis of Tool 2 (Pedagogy and Resources), the team discovered that all institutions utilized similar learning formats, implemented evidence-based learning strategies, and benefited from the advantages of classroom technology. The main difference between the two- and four-year institutions was in class size, typically ranging from 24 students to as many as 340 students, respectively, a more than 10-fold difference.

In the team's analysis of Tool 3 (Assessment) and the similarities thereof, the team discovered that the main differences lay in the use of partial and extra credit, and in the format and scoring of test questions. At the community college, instructors typically used free-response questions, and gave partial credit for work shown. Also, some instructors provided opportunities for extra credit. In contrast, the instructors at the four-year institution used multiple-choice questions exclusively to assess the depth of student understanding of content, and did not provide any opportunities for

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partial or extra credit. Differences in class size, as noted in Tool 2, accounted in large part for these varying assessment strategies. Team members acknowledged that free-response questions were superior for student assessment, but impractical to implement for very large classes. To work toward greater alignment in assessment, the team recommended that community college instructors introduce multiple-choice exam questions to help students prepare for future testing. Team members provided further support for this recommendation by citing the use of multiple-choice questions on ACS standardized exams.

On the basis of the overall findings of the three inventory-based tools, Tools 4 and 5 served as analytic summary tools. By leveraging the team's collective knowledge and experience, they were able to make thoughtful decisions about how best to move forward. Tool 4 summarized the differences identified in the analysis, and created strategies to address them. The team targeted areas within their reach, such as the advising recommendation described in the previous section. Some differences, such as class size, were acknowledged as significant but not within the scope of immediate change. Tool 5 summarized common curricular challenges and identified subsequent recommendations for alignment (see Table 5).

To meet the curricular challenges, the team developed an action plan to create open-access instructional resources that could promote the improved success for STEM students across all institutions. The development of these instructional resources became the final piece of the curricular alignment process. The resources also became examples of the kinds of action that teams could undertake as a result of their curricular analysis.

Curricular Action: Creating Instructional Resources

The Tools (1−5) discussed in this article became critical vehicles through which the team fostered a deep curricular awareness and engaged in significant curricular analysis. On the basis of this reflective and analytic work, the team created an action plan whereby students and chemistry faculty could benefit from their interinstitutional curricular alignment work. In the action plan, the team focused their expertise on two major action items: (i) a series of open-access learning modules in special content areas, and (ii) a restricted-access test bank of exam questions for faculty. The team members projected that these items would have widespread benefits for all partner institutions.

To address the first action item, the team created a set of engaging online instructional resources with the helpful assistance of graphic and technical experts on the university campus. Before getting started, the team surveyed existing online resources to make sure that they did not unnecessarily duplicate existing material. Based on this initial exploration, they chose not to rely on any sites that included inaccuracies, or that might not be maintained by its sponsors. Instead, the team turned its attention to creating modules that addressed concepts and skills from general chemistry. Given their analysis of the data from Tool 5, the team identified common curricular stumbling blocks and decided to focus on the following areas: inorganic nomenclature; six examples of reactions in solutions; and math for chemistry including significant figures, dimensional analysis, and fundamentals of algebra. The team then divided into subteams to design and develop module content with accompanying pretests, explanatory content, practice questions, and post-tests. They planned these modules for students who needed to review and reinforce the content of the first introductory course in chemistry, rather than to learn it for the first time.

To address the second action item, the team created a faculty test bank. This bank became a comprehensive vehicle to align assessment, particularly with regard to the difficulty of test questions presented in introductory chemistry. As part of this process, the team created question sets. Each partner institution contributed approximately 12 questions that addressed the chemistry topics compiled in Tool 1. The questions, ranked by team members as easy, moderate, or challenging, were assessed for clarity and then piloted with student volunteers. The final bank of test questions will serve as a shared resource to help instructional faculty align their test questions with the expectations of partner institutions. In particular, this resource is intended to help adjunct faculty and new faculty members who may have limited experience with assessment. Ultimately, the goal is for students to benefit from the consistency of shared expectations for assessment across partner institutions.

■ SUMMARY AND REFLECTION

With student success at the forefront of its mission, the chemistry team created a systematic and transferable model of curricular alignment that fosters curricular awareness, promotes curricular analysis, and facilitates curricular action. To drive that process, the team developed a set of inventory and analytic tools that are applicable to other disciplines and institutions, and can be modified easily for specific contexts. These tools have already been used and adapted by a mathematics curricular alignment team composed of faculty members from the same institutional partners. Finally, the team generated resources and recommendations as a way to support the team's instruction, and to illustrate to other faculty the possible action items that could be undertaken through collaboration.

To measure the direct benefit of this work on student performance metrics will remain a challenge. At UMBC, for example, there have been multiple units engaged in success efforts that target transfer and/or STEM students. Though preliminary data show that retention and graduation rates have improved for STEM transfer students (2012−2015), the campus-wide efforts make it difficult to tease out the particular impact, if any, of a relatively small chemistry team, or even the broader t-STEM Initiative. Yet, the intensive work of the faculty members generated a deep level of professional connection and engagement. Even after the original team commitment was fulfilled, the team quickly set to planning the next chapter of its work. As an initiative that was designed, in part, to create a sustainable context for professional collaboration, this commitment was a significant marker of success. This longevity was reflective of the efforts by the facilitator and the team to build a supportive community that focused on inquiry and analysis, rather than judgment and blame. The chemistry team identified openness and mutual respect as crucial elements of their productivity, and the adapted Wilder Collaborative Factors Inventory administered by the external evaluator to the larger t-STEM network echoed similar findings.[21] Because there is an element of emotional risk whenever faculty are asked to share, reflect, or consider change, the initial and ongoing work of creating a healthy curricular alignment process is essential.

Depending on the institutions and faculty members involved, there may be different ways to build these foundational elements, but the intention of the work must be authentic. Otherwise, negativity may derail good-faith efforts, and

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unchecked assumptions may undermine progress.[8,18] Ultimately, it is the central and deep commitment to student success that can encourage and sustain faculty participation in such efforts. If this commitment drives the work, collective energies become channeled toward the best ways to support all students. A comprehensive conception of curricular alignment that extends beyond "gap analysis" can also lessen the sense of risk and increase the sense of possibility. As with the chemistry team, this broader perspective can help to foster the kinds of significant reflections, collaborative discussions, and productive outcomes that will be increasingly important as STEM instruction shifts from traditional to more active learning pedagogies.[22,23] Without the willingness to engage beyond individualized classrooms and particular institutions, improving the educational experience for all of our students will remain beyond reach.

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Notes

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