University of Maine System
Program Integration
Round Two

Chemistry

Below please find a summary of the key points derived by the UMS Chief Academic Officers from the report provided by the **Chemistry** program integration team. The team's full report follows the CAOs' summary and recommendation.

UMS Chief Academic Officers' Summary and Recommendations

Chemistry

All institutions within the UMS offer some Chemistry courses. Two offer ACS Certified degrees and five offer a minor in Chemistry. Among the smaller campuses, chemistry courses are offered mainly in support of Biology and/or a variety of health profession programs.

Resources to support chemistry programs/offerings vary widely. All departments, however, often struggle to meet the demand for chemistry courses due primarily to an insufficient number of faculty.

Degrees awarded in Chemistry represent only a small fraction of the total number of bachelor's degrees offered in Maine or New England, but graduates with bachelor's degrees in Chemistry are not being produce in too high or too low numbers in Maine or New England. Demand is increasing, however, for a number of programs/careers that require Chemistry service courses.

RECOMMENDATIONS:

1. Alignment of Student Learning Outcomes for General Chemistry and Organic Chemistry:

This will include a report denoting a standardized equipment list to make sure that all campuses have the needed resources to support this alignment effort.
Timeline: (early spring 2017 semester, such that changes can go into effect for the following Fall 2017 semester)

2. Create K-16 partnership with high schools and local businesses, building upon current STEM outreach efforts (e.g. 4-H STEM ambassadors)
Timeline: (end of Spring 2017 semester)

3. Continue investigation into models of exemplary, on-line and/or hybrid Chemistry courses (with the understanding that this may be catering to non-majors)
Timeline: (end of Spring 2017 semester)

4. Work with University College to develop system-wide access to tutoring services
Timeline: (end of Spring 2017)

5. **Establish an annual UMS Chemistry conference.** Annual meeting of chemistry faculty will promote research and curricular collaboration as well as work sessions to advance work on initiatives outlined in recommendations 1 through 4. Annual meeting could include student research presentations.

PROGRAM INTEGRATION

CHEMISTRY SUB-COMMITTEE

REPORT

March 1, 2016

PROGRAM INTEGRATION

CHEMISTRY SUB-COMMITTEE

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Executive Summary

BACKGROUND

All institutions within the UMS offer some Chemistry courses. Two offer ACS Certified degrees and five offer a minor in Chemistry. Among the smaller campuses, chemistry courses are offered mainly in support of Biology and/or a variety of heath profession programs.

There are many instances of innovative and engaging teaching practices being employed in departments throughout the UMS:

- USM has taken an experiential approach to instruction in General Chemistry and all students engage in real world application of theory during the semester.
- UM has taken a studio approach to lab instruction and has modified its lab space to include small conference rooms where students can engage in collaborative learning activities.
- A faculty member at UMA has designed an on-line course for introductory chemistry that includes the use of laboratory kits in the students' homes.
- UMF has flipped the classroom in both General and Organic Chemistry so that students view videos of the lecture at home and come to class to solve problems and ask questions. Not only are many of the labs in Organic Chemistry are inquiry based, but students also get to design their own synthesis of a target compound.

Programs at UM and USM employ a full complement of full-time faculty whose areas of specialization span the sub-disciplines of chemistry. Many of the smaller campuses, however, rely on one or two individuals and/or one or two adjunct faculty to deliver a more limited range of course offerings.

Resources to support chemistry programs/offerings vary widely. All departments, however, often struggle to meet the demand for chemistry courses due primarily to an insufficient number of faculty.

Degrees awarded in Chemistry represent only a small fraction of the total number of bachelor's degrees offered in Maine or New England, but graduates with bachelor's degrees in Chemistry are not being produce in too high or too low numbers in Maine or New England. Demand is increasing, however, for a number of programs/careers that require Chemistry service courses.

RECOMMENDATIONS

Enhanced Quality:

1) Assure that students have the skills needed to succeed in chemistry courses
2) Provide academic support for students who may be struggling in their chemistry courses
3) Review and up-date the curriculum

4) Review and up-date teaching practices

Increased Access and Enrollment:

1) Increase transferability of courses by:
2) Review market data and update curriculum/programs as needed
3) Create K-16 partnerships
4) Encourage, and reward, faculty for participation in statewide educational and workforce development initiatives such as Project Login and Educate ME.

Increased Productivity and Financial Sustainability:

1. Consider shared programming that would allow smaller campuses with limited faculty to expand offerings and expertise available to students:
2. Improve retention and persistence to graduation through enhanced student support programming.

NOTE: ***The importance of adequate resources to support the above cannot be overstated.***

3. Professional development for faculty (including adjunct faculty) to improve productivity/quality
4. Partnerships with business/industry

Steps for Achieving Alignment of Student Learning Outcomes for General Chemistry and Organic Chemistry:

- Create a system-wide committee composed of at least one chemistry faculty member from each campus, and supported by curriculum design specialists with expertise in chemistry education (preferably) or science education, to develop a set of common learning outcomes for General Chemistry.

- Create a second system-wide committee composed of at least one chemistry faculty member from each campus, and supported by curriculum design specialists with expertise in chemistry education (preferably) or science education, to develop a set of common learning outcomes for Organic Chemistry
- Allow one academic year for each committee to complete its task
- Provide material support for the effort

Steps for Alignment of Course Name and Course Numbering for General Chemistry and Organic Chemistry Courses:

This can be incorporated (as the final step in the process) into the charge for the committees tasked with developing common learning outcomes for General and Organic Chemistry courses.

REPORT

A. BACKGROUND

Process:

The Program Integration Chemistry Sub-Committee met face to face three times: September 26, 2015; November 13, 2015; and January 21, 2016. The team also met via PolyCom twice: October 23, 2015; and November 6. Between meetings data was gathered via email and information/documents were made available to team members through a shared Google Docs folder.

Current Status of Chemistry in the UMS:

All institutions within the UMS offer some Chemistry courses. Two offer ACS Certified degrees and five offer a minor in Chemistry. Among the smaller campuses, chemistry courses are offered mainly in support of Biology and/or a variety of allied health programs.

There are many instances of innovative and engaging teaching practices being employed in departments throughout the UMS:

- USM has taken an experiential approach to instruction in General Chemistry and all students engage in real world application of theory during the semester.
- UM has taken a studio approach to lab instruction and has modified its lab space to include small conference rooms where students can engage in collaborative learning activities.
- A faculty member at UMA has designed an on-line course for introductory chemistry that includes the use of laboratory kits in the students' homes.
- UMF has flipped the classroom in both General and Organic Chemistry so that students view videos of the lecture at home and come to class to solve problems and ask questions. Not only are many of the labs in Organic Chemistry are inquiry based, but students also get to design their own synthesis of a target compound.

Table I: Degrees Offered by Institution

Institution	Undergrad Enrollment FTE (Fall2015 Census)	Chemistry Degrees/Programs Offered	ACS Certified	# Chemistry Faculty (FTE)			
				Tenure Track	Lecturers	Adjuncts	Total FTE
UM	5920	BA;BS;BS-ACS Cert.; BS-Pre Med; BS – Pre Pharm; Minor	Yes	8.5	3	1	12.5
UMA	2522	NA		1			1
UMF	1367	Minor; Secondary Education Conc. In Chemistry		2		1	3
UMFK	763	NA				1	1
UMM	405	Minor		1.5			1.5
UMPI	715	Minor		1			1
USM	3873	BA; BA (Secondary Ed Conc.); BS (Bio-Chem); BS-ACS Cert.; Minor; Minor (BioChem);	Yes	5	1	3	9

Table II: Introductory, General Chemistry, and Organic Chemistry Courses Offered by Institution

Institution	Course #	Course Name	# Students	Lab Required	Lab Course #
UM	CHY 101	Chemistry for Everyday Living	20-30	Y	CHY 102
	CHY 121	General Chemistry I	550 (FA); 130 (SP); 30 (SUM)	Y	CHY 123
	CHY 122	General Chemistry II	330 (SP); 30 (SUM)	Y	CHY 124
	CHY 131	General Chemistry (one semester)	150 (FA)	Y	CHY 133
	CHY 251	Organic Chemistry I	330	Y	CHY 253
	CHY 252	Organic Chemistry II	215		CHY 254
UMA	CHY 100	Fundamentals of Chemistry	68 (SP)	Y	Included

	CHY 105	Fundamentals of Chemistry	39 (FA)	Y	CHY 106
	CHY 108	Allied Health Chemistry	49 (FA); 25 (SP)	Y	Included
	CHY 115	General Chemistry I	39 (FA)	Y	Included
	CHY 116	General Chemistry II	21 (SP)	Y	Included
	CHY 117	Introduction to Organic and Biochemistry	17 (FA)	Y	Included
	CHY 211	Organic Chemistry I	27 (SUM)	Y	Included
	CHY 212	Organic Chemistry II	20 (SUM)	Y	Included
	CHY 221	Organic Chemistry	20 (SUM)	Y	Included
UMF	CHY 110	Elementary Chemistry	64/yr	Y	Included
	CHY 141	General Chemistry I	64-80	Y	Included
	CHY 142	General Chemistry II	48-64	Y	Included
	CHY 241	Organic Chemistry I	20-32	Y	Included
	CHY 242	Organic Chemistry II	16	Y	Included
UMFK	CHY 100	Chemistry I	32	Y	Included
	CHY 101	Chemistry II	16	Y	Included
	CHY 310	Organic Chemistry I	40	Y	Included
	CHY 311	Organic Chemistry II	40	Y	Included
UMM	CHY 101	General Chemistry I	20/yr	Y	Included
	CHY 102	General Chemistry II	16	Y	Included
	CHY 113	Forensic Science	12	Y	Included
	CHY 221	Organic Chemistry I	16	Y	Included
	CHY 224	Organic Chemistry II	10	Y	Included
UMPI	CHY 111	General Chemistry I	Up to 72 (2 sections of 36)	Y	Included
	CHY 122	General Chemistry II	18	Y	Included
	CHY 221	Organic Chemistry I	18	Y	CHY 221L
	CHY 222	Organic Chemistry II	18	Y	CHY 222L
USM	CHY 107	Chemistry for Health Sciences	350		
	CHY 113	Principles of Chemistry I	240 (FA); 100 (SP);	Y	CHY 114
	CHY 115	Principles of Chemistry II	120 (SP); 50 (SUM)	Y	CHY 116
	CHY 251	Organic Chemistry I	90 (FA); 55 (SUM)	Y	CHY 252
	CHY 253	Organic Chemistry II	80 (FA); 50 (SUM)	Y	CHY 254

Programs at UM and USM employ a full complement of full-time faculty whose areas of specialization span the sub-disciplines of chemistry. Many of the smaller campuses, however, rely on one or two individuals and/or one or two adjunct faculty to deliver a more limited range of course offerings.

Resources to support chemistry programs/offerings vary widely. UM and USM for example have separate, dedicated laboratory space for General Chemistry, Organic Chemistry, and Analytical Chemistry while the UMA-Bangor campus has only two laboratories - one shared by General Chemistry and Biology, and the other by Organic Chemistry and Microbiology. Access to instrumentation and laboratory equipment is uneven as well. AT UMPI there was little instrumentation and no designated space for research until late 2015. These improvements were due to the passage of the 2013 STEM Bond Issue. As a result the faculty member at UMPI carried out research at a SUNY campus in NY.

Chemistry departments throughout the UMS are under resourced. As a result, these departments often struggle to meet the demands for chemistry courses due primarily to an insufficient number of faculty.

The perception among some faculty at the research universities is that students from these campuses who transfer into chemistry programs at the research centers are unprepared to meet the challenges of these programs; however, no study to gather reliable data to test this hypothesis has ever been conducted. Admissions policies do vary across the campuses.

Table III: Department Assets

Institution	Course	Description of Laboratory Space	Teaching Equipment
UM	CHY 102		
	CHY 123	40 sections (FA); 30 sections (SP); 2 sections (SUM) 6 labs in very good condition w/capacity of 16 (96 total at a time); 2 in poor condition w/capacity of 18 (38 at a time). Labs have breakout rooms (small classrooms) to allow for studio-like approach to teaching	UV-Vis & IR Spectrometers networked through the InterChemNet online program; pH meters; glassware; Bunsen burners
	CHY 124	24 sections (SP); 2-3 sections (SUM) 6 labs in very good condition w/capacity of 16 (96 total at a time); 2 in poor condition w/capacity of 18 (38 at a time). Labs have breakout rooms (small classrooms) to allow for studio-like approach to teaching	UV-Vis & IR Spectrometers networked through the InterChemNet online program; pH meters; glassware; Bunsen burners
	CHY 133	8 sections (FA); 20-24 students each	UV-Vis & IR Spectrometers networked through the InterChemNet online program; pH meters; glassware; Bunsen burners
	CHY 253	12 sections (FA); 2 sections (SP); 2 sections (SUM) 2 fair labs w/capacity of 16 (32 total)	Varian 400 MHz NMR; Thermo Scientific picoSpin NMR; FTIR; GCMS; Vernier/LabQuest laboratory equipment; microscale organic glassware
	CHY 254	8 sections (SP); 2 sections (SUM)	Varian 400 MHz NMR; Thermo

		2 fair labs w/capacity of 16 (32 total)	Scientific picoSpin NMR; FTIR; GCMS; Vernier/LabQuest laboratory equipment; microscale organic glassware
UMA	All	• UMA-Bangor has 2 science labs, each with a capacity of 20. One lab is shared by General/Introductory Chemistries & Biology; the other is shared by Organic Chemistry & Microbiology. UMA- Augusta has 1 Chemistry lab with ten group stations (for 2 students ea.) • UMA-Augusta campus has one chemistry lab w/5 ventilation hoods, and 10 group lab stations (2 students /station = capacity of 20)	Drying oven; digital pH meters; melting point apparatus; Spec-20s; electronic balances; UV-spectrometer; microscale organic chemistry sets with sand bath heating units
UMF	CHY 110	New lab, 16 capacity; old lab, 16 capacity	IR Spectrometer UV Spectrometer Gas Chromatograph GC-Mass Spectrometer H & C NMR spectrometer
	CHY 141	New lab, 16 capacity, 4-5 sections	
	CHY 142	New lab, 16 capacity, 3-4 sections	
	CHY 241	New lab, 16 capacity, 1-2 sections	
	CHY 242	New lab, 16 capacity, 1 section	
UMFK	CHY 100	One Chemistry lab services all Chemistry courses	
	CHY 101		
	CHY 310		
	CHY311		
UMM	CHY 101	New lab, 24 capacity, 2 sections	
	CHY 102	New lab, 24 capacity, 2 sections	
	CHY 113	Old lab (adequate) shared w/Molecular Bio, 18 capacity, 1 section	
	CHY 221	Old lab (adequate), 18 capacity, 1 section	
	CHY 222	Old lab (adequate), 18 capacity, 1 section	
UMPI	All	One chemistry lab serves for General, Organic, and Bio Chemistries. Lab has capacity of 18	As of Spring 2016 – PicoSpin 80 NMR; FT-IR w/ two rotary evaporators
USM	CHY 114	11 sections (FA); 6 sections (SP) Very old (inadequate) lab, capacity 18, new lab currently under construction	Vernier probes (pH, conductivity, turbidity); UV-Vis; GC; spec 20
	CHY 116	Same as CHY 114	Same as CHY 114
	CHY 252	4 sections (FA); 2 sections (SP) Good lab, 18 capacity	2 ATR FT-IRs; GC-MS; GC; 60 MHz and 300 MHz NMR; roto-vaps; microscale equipment
	CHY 254	2 sections (FA); 2 sections (SP) Good lab, 18 capacity	Same as CHY 252

<u>Demand for Chemistry Programs/Degrees</u>:

Chemistry is not on the list of the 12 highest demand programs/careers in either Maine or New England. Many of programs which require chemistry courses, however, are on the list (e.g.Biology, many programs in the health professions, and Engineering). Similarly Chemistry does not make the list of bachelor degree occupations with the highest number of annual openings in Maine or New England, but Engineering does. Degrees awarded in Chemistry represent only a small fraction of the total number of

bachelor's degrees offered in Maine or New England (see table IV). Interestingly, according to the market analysis data provided to the team, graduates with bachelor's degrees in Chemistry are not being produce in too high or too low numbers in Maine or New England. Demand is increasing, however, for a number of programs/careers that require Chemistry service courses.

Table IV: % of College Bound Seniors Intending to Major in Chemistry

Cohort:	2011	2012	2013	2014	2015	% change 2011-2015
Maine	1.4%	1.3%	1.4%	1.2%	1.3%	-0.1%
Total College Bound HS Srs.	6708	7269	6814	6315	6689	
New England	1.8%	1.7%	1.5%	1.4%	1.4%	-0.3 %
Total College Bound HS Srs.	82,502	80,181	70,993	62,938	65,248	

B. RECOMMENDATIONS

<u>Enhanced Quality</u>:

3) Assure that students have the skills needed to succeed in chemistry courses
   - Add robust pre-requisites to introductory courses (e.g. well defined math, reading, and writing competencies)
   - Assess student readiness/preparation before enrolling in courses

4) Provide academic support for students who may be struggling in their chemistry courses
   - Provide supplemental instruction and an on-line program (e.g. Web Assign, Chem Prep) for practice for students whose academic background/performance is borderline
   - Identify students at risk and provide early interventions such as
     - Imbedded class tutors
     - Supplemental instruction (e.g. recitations)
     - Peer Led Team Learning
     - On-line resources to students to supplement instruction (e.g. BOLT)
     - Wide access to tutoring services
     - Wide access to mentoring services

3) Review and up-date the curriculum

- Develop common numbering and a common set of learning outcomes for General Chemistry and Organic Chemistry courses, lecture and lab, to ensure consistent quality and facilitate transfer.
- Establish common pre-requisites for General Chemistry and Organic Chemistry Courses

4) Review and up-date teaching practices

- Provide professional development in pedagogy for faculty.
- Consider requiring new faculty hires to participate in a year-long training in teaching and learning. Provide one course release in exchange for participation.
- Acquaint faculty with the existence of educational technologists and encourage faculty to consult with them as they design new courses.
- Define high quality teaching practice and incorporate into the tenure and promotion process.
- Provide training and professional development in advising for faculty.
- When a higher standard of scholarship (i.e. required research and publications) is instituted at the non-research institutions, a concomitant adjustment in teaching load should be made.

Increased Access and Enrollment:

5) Increase transferability of courses by:
   - establishing a common course numbering scheme
   - establishing common learning outcomes in foundational courses
   - establishing common assessment standards

6) Review market data and update curriculum/programs as needed

7) Create K-16 partnerships to:
   - engage students early on and
   - assist students in exploring careers in Chemistry
   - create an awareness/understanding among K-12 educators of what it means from college faculty perspective to be college ready
   - create high-quality, sustainable concurrent enrollment partnerships with feeder high schools
   - create summer bridge programs for incoming first-year students
   - establish expectations for partnerships with business and industry

8) Encourage, and reward, faculty for participation in statewide educational and workforce development initiatives such as Project Login and Educate ME.

Increased Productivity and Financial Sustainability:

5. Consider shared programming that would allow smaller campuses with limited faculty to expand offerings and expertise available to students:
   - on-line, or other distance modality, for non-science majors;
   - low-residency, hybrid arrangements for science majors.

6. Improve retention and persistence to graduation through enhanced student support programming such as:

- New Student Orientation
- Mentoring
- Imbedded tutors
- Supplemental instruction
- On-line tutoring resources (Chemistry analog of Vault)
- Development of early warning systems that identify at risk students and begin interventions within the first three weeks of a semester
- Implementation of High Impact Teaching practices
    - First-Year Experiences
    - Common Intellectual Experiences
    - Learning Communities
    - Writing-Intensive Courses
    - Collaborative Assignments and Projects
    - Undergraduate Research
    - Diversity/Global Learning
    - Service Learning, Community-Based Learning
    - Internships
    - Capstone Courses and Projects
- Implementation of high quality assessment practices

NOTE: ***The importance of adequate resources to support the above cannot be overstated.***

7. Professional development for faculty (including adjunct faculty) to improve productivity/quality

8. Partnerships with business/industry

<u>Steps for Achieving Alignment of Student Learning Outcomes for General Chemistry and Organic Chemistry</u>:

- Create a system-wide committee composed of at least one chemistry faculty member from each campus, and supported by curriculum design specialists with expertise in chemistry education (preferably) or science education, to develop a set of common learning outcomes for General Chemistry.
- Create a second system-wide committee composed of at least one chemistry faculty member from each campus, and supported by curriculum design specialists with expertise in chemistry education (preferably) or science education, to develop a set of common learning outcomes for Organic Chemistry
- Allow one academic year for each committee to complete its task
- Provide material support for the effort:
    - Travel reimbursement for quarterly face-to-face meetings

- Budget for acquisition of texts and articles to support research of the literature on best practices
- Budget for a couple committee members to travel to model institutions/programs and/or to bring in representatives of model institutions/programs to meet with the committee
- Clerical support for note taking, scheduling/arranging face-to-face and virtual meetings, assistance in collection of data and production of final report.

Steps for Alignment of Course Name and Course Numbering for General Chemistry and Organic Chemistry Courses:

This can be incorporated (as the final step in the process) into the charge for the committees tasked with developing common learning outcomes for General and Organic Chemistry courses.

Data/Resources Needed:

- Listing of a broad range of the career options (i.e. not necessarily limited to the field of chemistry) available to Chemistry graduates in Maine
- Study of the success rates for students transferring from rural campuses to chemistry departments at research institutions
- Broader access to market study results for chemistry and related fields/occupations
- Models of exemplary, on-line and/or hybrid Chemistry courses [NOTE: most committee members felt that on-line Chemistry courses were more appropriate for liberal arts/non-majors courses]