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Best Organic Chemistry Practices in the Midwest

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Pedagogy in Organic Chemistry Courses in the Great Lakes States

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Introduction

Organic chemistry is a cornerstone of chemistry in higher education. Its contents are heavily relied upon in upper-level chemistry courses, including biochemistry and physical chemistry. Carbon chemistry is so vital to the understanding of the world around us, as nearly everything we encounter relies, in some way, upon carbon chemistry. It is no wonder, then, that organic chemistry, often taught in two adjoining courses, both with a lab component, is required in most pre-health majors. In fact, it is unlikely that one will find a chemistry-related degree that does not require some kind of organic chemistry for graduation.

Unfortunately, organic chemistry is often labeled as a "weed-out" course. It is notorious across the nation for its high fail, high withdrawal rate. The curriculum is rigorous; the course has a reputation for being time-consuming and complicated. Often, this reputation alone causes students to reconsider their degrees. However, the goal of these courses should not be to scare students into changing their majors, but rather, to build the foundations for the rest of their higher-level chemistry education. How do we rid these two courses of the stigmata they carry and better prepare students for the courses that follow organic chemistry? The goal of this thesis is to see how consistent the teaching practices of organic chemistry lecturers is across the Great Lakes states, and how these teaching styles may correlate to a better understanding of the course.

Western Michigan University (WMU) is not immune to the difficulties that come with pedagogy in organic chemistry. As of the 2017-2018 school year, Organic Chemistry I is ranked the sixth most failed class offered at the university, with a drop/fail/withdrawal (DEWI) rate of 53.5% of total students enrolled, and Organic Chemistry II has a 36.9% DEWI rate (Gateways to Completion). Having recently taken this course at WMU, as well as serving as a learning assistant (LA) for the Fall 2018 semester, I have had the unique experience of seeing both sides of this problem. As a student, I remember the stressors that came with preparing for exams, understanding concepts, and trying to retain this information for Organic II. As an LA, I saw much of the same mindset in the students I taught, but I also saw the struggles of writing exams, the time that goes into grading, and the struggle of attempting to lower the DEWI rate while still ensuring students fully grasp the important concepts of Organic I.

WMU has made some strides in offering course assistance to courses with high DEWI rates. Supplemental Instructors, that is, undergraduate students trained to hold study session hours, attend class, and serve as a “model” student in a class they have recently taken and scored a grade of “BA” or higher in have been consistently available to instructors, though it is at the instructor’s discretion as to whether SIs are incorporated into their class (Western Michigan University). As of recently, Student Success Services as made LAs available for Organic I. LAs differ from SIs in that LAs can facilitate activities and teaching during lecture time, whereas SIs are expected to model good student behavior in class by taking notes and being present. In addition to these two student positions, students struggling in gateway classes can attend drop-in tutoring hours for a more one-on-one experience.

The idea for this thesis came about from this perspective I gained from assisting in teaching the course; do all schools struggle with similar issues as WMU? How are they remedied? How feasible would it be for WMU to adopt the ideas of other institutions into their current curriculum?

Before this question is answered, we must look to the American Chemistry Society, or ACS, as WMU and all its higher-education counterparts, barring community colleges, have an ACS-certified chemistry curriculum. What does this mean in terms of standardization? The ACS aims to better chemical education from K-12 to graduate programs. Its broad goals, in terms of education, are to, “[promote] lifelong, rigorous education of science in formal and informal settings and [ensure] that all students understand science in accordance with national standards. [To encourage] state and federal support for science education facilities and teacher education and training. [To support in] nurturing students of all backgrounds, particularly those from underrepresented groups, in pursuit of studies and careers in STEM.” The mission statement of the ACS in terms of organic chemistry states that, “an introductory sequence should drive the student to appreciate the breadth of organic chemistry by facilitating an understanding of the principles, and the practice of applying them, to gain a working knowledge and appreciation of organic structure and reactivity.” The conceptual topics of the ACS organic chemistry curriculum includes bonding and how structure affects reactivity of organic molecules; electronic, steric, and orbital interactions between organic molecules; non-covalent interactions; solvent effects; Lewis and

Brønsted acid-base chemistry; stereochemistry; addition, elimination, substitution, and rearrangement mechanisms as well as their respective intermediates; functional groups; organic and retrosynthesis; and methods of activation, free radical chemistry, and organometallic catalysis (ACS Organic Chemistry Supplement).

The ACS' "practical topics" concern themselves with the laboratory outcomes of both courses. These outcomes include understanding general procedures and use of laboratory equipment; how the choice of solvent pertains to an experiment; lab safety; recording laboratory data; monitoring a reaction; isolation and purification of products; spectroscopic analysis of results and accurately interpreting said results; analyzing experimental data using statistical analysis; and understanding the value and limitations of computational methods (ACS Organic Chemistry Supplement).

The ACS encourages what most schools already use in their organic chemistry curriculum: a two-semester sequence of lectures, both with accompanying labs. It is imperative that the lecture and lab reinforce one another. It is generally taught in the second year, but the ACS states that many institutions offer the courses in the first year with good success rates.

A one-semester foundation course covering fundamentals used in a variety of courses, including biochemistry, is also encouraged by the ACS. The topics suggested include: carbonyl chemistry; introductions to nucleophilic addition, alkylation, and condensation reactions; oxidation and reduction chemistry; addition and elimination reactions; acidity and basicity trends of organic compounds; stereochemistry, and how it applies to the topics previously listed; resonance; aromaticity; and basic spectroscopy of the topics previously listed.

However, even with the clear instructions from the ACS on organic chemistry curricula, we see an unusually high fail, high withdrawal rate. Most organic chemistry lectures are taught in a "traditional" manner; that is, class is held in a large lecture hall with a large number of students, and one lecturer will present information to the class by means of the board or Powerpoint presentation. Though this is the most common form of lecturing, is it the best way to teach students about the difficult concepts of carbon chemistry?

Crimmins and Midkiff explore how teaching methods of these notoriously difficult courses affect student success rates. In their study, they state that the standard Organic I classroom lecture uses the traditional approach, despite the high numbers of students who fail or withdrawal from the class completely. In their study, conducted at the University of North Carolina at Chapel Hill (UNC-CH), Crimmins and Midkiff redesigned the Organic I lecture, instead focusing on using active learning techniques, defined as "any instructional method that actively engages students in the learning process while in the classroom." The types of active learning implemented in the UNC-CH classroom included learning objectives for each section of the course, given to students at the beginning of the course as a study guide; socratic learning, where the instructor presented frequently missed questions and "solicited answers from students who raised their hand, cold-called on individuals, or solicited a group response through raising of hands;" clicker questions, and other types of hands-on learning to encourage students to be active in their learning. Crimmins and Midkiff took from four groups of students in the course; the first two coming from 2002 and 2003, and the second two ten years later, in 2012 and 2013, each tested with the same test questions. They found that, in the "postintervention" groups, the average grade was a B-, whereas the "comparison" group prior to the change in learning style held an average grade of a C+ (2017). This suggests that active learning in organic chemistry positively affects students' understanding of the material presented.

Another popular alternative to traditional classroom learning is implementing a "flipped" classroom, where students learn the material at home through online lectures and the textbook, and are encouraged to write their questions down as they go along. These questions can then be posed in lecture, which serves to better strengthen the concepts presented at home and work through examples as a class. Christiansen compared two groups, one of which implemented traditional teaching, another that used flipped, or "inverted" teaching. Though data for the inverted teaching group has yet to be published, Christiansen found that those taught by inverted teaching attended class more often and were motivated to watch online lectures through weekly quizzes given (2014). In addition to this, though it was time-consuming for instructors to create the online lectures, these lectures may be used indefinitely and will ultimately save time in the long run. Using a flipped classroom setting may remedy many of the problems faced in organic chemistry courses.

While the flipped classroom is a viable option for a course as intensive as organic chemistry, Christiansen did note that many students could not find time to watch online lectures outside of class (2014). Many only had the time allotted for the lecture hour, and their grade suffered as a result of this. However, there are ways in which one might implement the general idea of inverted teaching in a larger classroom. Lyon and Lagowski found, in a study where a class of roughly 500 chemistry students were often broken off into small learning groups to discuss difficult problems, did better than their conventionally-learning counterparts both in terms of examinations and in overall course grades (2008). While a flipped classroom setting may seem daunting and overwhelming, perhaps a smaller change, such as implementing group work in a larger classroom setting, would be an easier administration change that may yield similar results as a flipped classroom. Canelas et al. found that there was no distinct difference in the amount of time spent on preparing for an active learning lecture as opposed to a traditional lecture designed for passive learning, indicating that larger classrooms should have little difficulties transitioning to a learning environment that is proven to yield higher success rates than what is currently widely used (2017).

Understanding the different methods for lecturing is vital for increasing overall retention and performance in the classroom and laboratory setting. The purpose of this study is to understand how teaching a difficult course such as organic chemistry can be a determining factor in the success of students. We have come to understand that active learning styles coupled with a recitation hour seems to be the formula that yields the best results in terms of success rates of students. We define “success” here as a student who achieves a grade of “C” or above. By surveying instructors of organic chemistry across four categories of higher level institutions, including community colleges, liberal arts colleges, research-intensive institutions, and regional state institutions across the Great Lakes region; that is, Wisconsin, Illinois, Indiana, Ohio, and Michigan, we hope to gain a better understanding of how a successful organic chemistry lecture is given, and what teaching methods tend to yield the best results. With these findings, we hope to demonstrate the importance of pedagogy in higher education, specifically in STEM.

A survey-style study was conducted to determine what institutions have the best organic chemistry practices within the Great Lakes States: Illinois, Wisconsin, Michigan, Indiana, and Ohio. It is hypothesized that class size, the incorporation of the lab with the lecture, and the standardization of the grade scale within an institution would play a key role in the overall success rate of students. The success rate here is defined as a low DEWI rate within the two courses, Organic Chemistry I and Organic Chemistry II, of an institution. Regional state institutions will have the most similar practices to WMU, and each institution in one subset will have similar practices to the others within the subset.

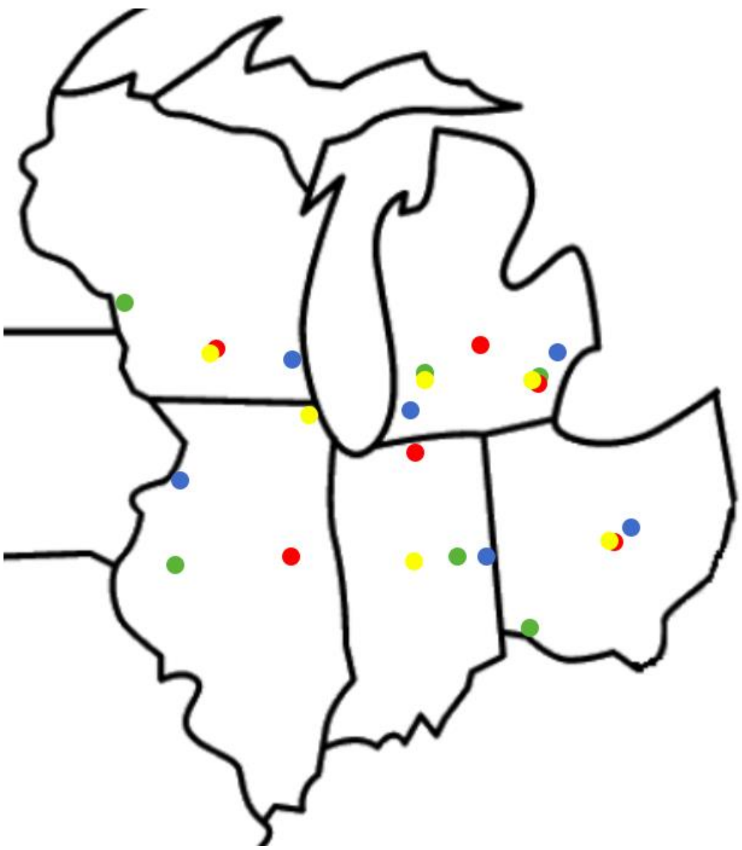
Methods

Twenty-four higher-learning institutions were asked to participate in the study. The schools were divided into the following categories: two-year community colleges, four-year liberal arts colleges, research-heavy institutions, and regional state institutions. One school of each category represented one state in the Great Lakes region: Wisconsin, Illinois, Indiana, Ohio, and Michigan. Michigan was divided into east and west sides of the state, as the focal point of the study is to learn how to better teach organic chemistry in WMU. The schools chosen for each category based upon their acceptance rates, SAT scores, Carnegie classification, and whether the institution was ACS accredited. The only category where ACS credit was not a determining factor was for community colleges; no schools in this category were ACS accredited. The schools used in this study can be found below.

A twenty-three question survey consisting of three separate sections: 1) Course Structure, 2) Standardization, and 3) Content and Outcomes was created using Google Forms. The first section focused on questions about class size, textbook and edition, lab book, prerequisites, supplemental instruction given, and if any recitation is offered in the course. The standardization section focused on how the chemistry department of each institution ensures standardization of both Organic I and Organic II, and how instructors write their exams and expect students to study. The content and outcomes section of the survey were more concerned with end goals of each class, and also asked if the instructor was willing to share the pass rate of the course taught. A basic outline of each question used can be found below. No questions given in the survey, barring a question about what institution the instructor teaches at and a question about what email may be used for further contact, were required; many institutions had multiple instructors, some of which only teach one of the courses and thus cannot answer for the other course. The questions where multiple choice was used also gives each option for the question.

At the end of the survey, instructors were asked if they were comfortable sending a recent syllabus. This was also mentioned in the emails reminding instructors of the survey.

Figure 1: Map of Institutions used for this Study



Key:

Regional State Institutions	Green

Community Colleges	Yellow
Research Intensive Institutions	Red
Liberal Arts Institutions	Blue

Table 1: Institutions Chosen for this Study

Institution	Category	Location	Population	ACS accredited?	Avg. SAT	Carnegie Basic Classification	Acceptance Rate
West Michigan							
Kalamazoo Valley Community College	Community College	Kalamazoo, MI	10,192	No	n/a	igh Transfer-High Traditional	n/a
Andrews University	Four-year liberal	Berrien Springs	1,704	Yes	1179	Doctoral/Professional Universities	39

	arts college	, MI					
Michigan State University	Research-intensive university	East Lansing, MI	38,996	Yes	1204	Doctoral Universities: Very High Research Activity	66
Western Michigan University	Regional state institution	Kalamazoo, MI	17,936	Yes	1090	Doctoral Universities: High Research Activity	82
East Michigan							
Oakland Community College	Community College	Bloomfield Hills, MI	26,405	No	n/a	Associate's Colleges: Mixed Transfer/Career & Technical-Mixed Traditional/Nontraditional	n/a
Rochester College	Four-year liberal arts college	Rochester Hills, MI	1,153	No	1090	Baccalaureate Colleges: Diverse Fields	58
University of Michigan	Research-intensive university	Ann Arbor, MI	29,821	Yes	1380	Doctoral Universities: Very High Research Activity	26
Eastern Michigan	Regional state	Ypsilanti, MI	16,997	Yes	1100	Doctoral Universities: High Research Activity	75

University	institution						
Illinois							
College of Lake County	Community College	Grayslake, IL	17,685	No	n/a	High Career & Technical-High Traditional	n/a
Augustana College	Four-year liberal arts college	Rock Island, IL	2,647	Yes	1260	Baccalaureate Colleges: Arts & Sciences Focus	49
University of Illinois	Research-intensive university	Champaign County, IL	33,955	Yes	1270	Doctoral Universities: Very High Research Activity	66
Western Illinois University	Regional state institution	Macomb, IL	7,599	Yes	1080	Master's Colleges & Universities: Larger Programs	60
Ohio							
Columbus State Community College	Community College	Columbus, OH	27,109	No	n/a	Associate's Colleges: Mixed Transfer/Career & Technical-Mixed Traditional/Nontraditional	n/a
Denison	Four-year	Granvil	2,34	Yes	1290	Baccalaureate Colleges: Arts &	48

University	liberal arts college	le, OH	1			Sciences Focus	
Ohio State University	Research-intensive university	Columbus, OH	45,946	Yes	1260	Doctoral Universities: Very High Research Activity	49
University of Cincinnati	Regional state institution	Cincinnati, OH	26,608	Yes	1233	Doctoral Universities: Very High Research Activity	86
Wisconsin							
Madison Area Technical College	Community College	Madison, WI	17,463	No	n/a	Baccalaureate/Associate's Colleges: Associate's Dominant	n/a
Mount Mary University	Four-year liberal arts college	Milwaukee, WI	735	No	1010	Master's Colleges & Universities: Medium Programs	53
University of Wisconsin – Madison	Research-intensive university	Madison, WI	32,196	Yes	1359	Doctoral Universities: Very High Research Activity	58
University of Wisconsin-La	Regional state	La Crosse,	9,655	Yes	1225	Master's Colleges & Universities: Larger Programs	80

Crosse	institution	WI					
Indiana							
Ivy Tech Community College - Indianapolis	Community College	Indianapolis, IN	75,486	No	n/a	Associate's Colleges: Mixed Transfer/Career & Technical-Mixed Traditional/Nontraditional	n/a
Earlham University	Four-year liberal arts college	Richmond, IN	1,128	Yes	1295	Baccalaureate Colleges: Arts & Sciences Focus	62
University of Notre Dame	Research-intensive university	Notre Dame, IN	12,467	Yes	1445	Doctoral Universities: Very High Research Activity	20
Ball State University	Regional state institution	Muncie, IN	22,513	Yes	1150	Doctoral Universities: High Research Activity	62

Figure 2: Google Form Survey Template

Course Structure: The set of questions below are concerned with the overall structure of both courses.

1. Is the lab a portion of the lecture grade, or is the lab a separate course?
    a. The lab is graded separately from the lecture hour.
    b. The lab and the lecture hour are graded together.
    c. The lab is graded separately for Organic I, but graded with the lecture for Organic II.

   d. The lab is graded separately for Organic II, but graded with the lecture for Organic I.

2. What lab book is required for both courses? Is this book used for both labs?
3. What textbook and edition of the book is used in both courses?
4. What is the average class size over the last five years for Organic I?
   a. 1-24
   b. 25-49
   c. 50-74
   d. 75-99
   e. 100-149
   f. 150-199
   g. 200-249
   h. 250+
5. What is the average class size over the last five years for Organic II?
   a. 1-24
   b. 25-49
   c. 50-74
   d. 75-99
   e. 100-149
   f. 150-199
   g. 200-249
   h. 250+
6. What are the prerequisites of Organic I? Are there any placement tests, or are students only expected to pass the prerequisite(s)?
7. What major(s) require both courses for their program?
8. Are there TAs involved in the course? If so, how are they involved?

9. What type of supplemental instruction (learning assistants, SI leaders, tutoring) is offered for both courses?
10. Is there a recitation time offered in the course? If so, how much time per week?

Standardization: The questions in the following section are concerned with how your department standardizes both courses across semesters and instructors.

1. As a matter of policy, do you try to keep the same instructor for the second semester follow-up course?
2. If the two courses are taught by different instructors, how does the department ensure standardization between different instructors?
3. Is the grading standardized by the department? If not, who sets the grade scale?
4. What are the required components of an overall course grade? How are they weighted?
5. How do instructors expect students to study for exams?
6. Are exams multiple choice, written, or a mix?
    a. Multiple choice
    b. Written
    c. Mix
7. How often do instructors get together to talk about modifying the curriculum? Does your institution provide resources for that evaluation?

Content and outcomes: The following set of questions concern themselves with the content and end goals of both courses.

1. Do you prefer to teach addition reactions or substitution reactions first, and why?
2. How much emphasis is put on learning name reactions vs. mechanisms? E.g. Williamson Ether reaction is taught as an Sn2 reaction.
3. What are the five most important skills the students need to learn in organic chemistry as a whole?
4. Is there anything else you'd like to tell me regarding Organic I and II?

5. If you are willing to share, what is the approximate number of students who score lower than a C for each course?
6. Would you mind if I contacted you to ask follow-up questions to strengthen my thesis? What is the best way to reach you?

The Organic Chemistry instructors were then contacted via email to ask if they were willing to participate in the survey. A follow-up email was sent two weeks after initial contact, then phone calls were placed to each instructor who did not answer the survey.

Results

Table 2: Number and Type of Institution that Responded to the Google Survey

Institution Type	Number of Responses
Community Colleges	2
Four-Year Liberal Arts	3
Regional State Institutions	3

While 24 schools in total were contacted, only eight excluding WMU responded to the survey. Thus, these results cannot be considered statistically significant. If a follow-up study were conducted, it is suggested that this number be doubled or tripled to ensure ample data can be collected. In addition to this, no institutions sent syllabi. In the future, an emphasis on receiving syllabi should be made, as the information given is extremely pertinent to this study. Although no statistics can be performed, some interesting patterns were found within the eight responses when compared to the WMU instructor's answers to the same survey.

Of the eight schools that responded, two fell within the “regional state schools” category; two fell within the “two-year community colleges” category; and three fell under the “four-year liberal arts institutions” category. The unaccounted for institution responded to the survey prior to the addition of the two required questions regarding the name of the institution and an email to contact the instructor. The results will still include this response, but the responses will not be assigned to a specific type of institution and will instead only be used to compare its responses to the instructor from WMU.

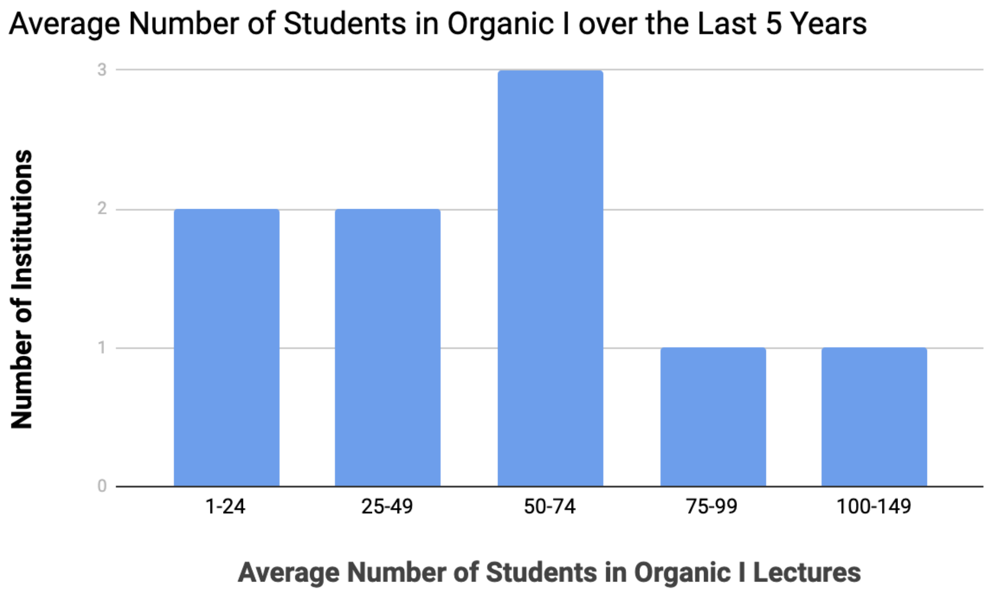
Course Structure

Of the eight schools surveyed, five had a lab hour that was graded with the lecture. This included two liberal arts universities, two community colleges, and one regional state institution. WMU treats the lecture as a three-credit class and the lab as its own one-credit class, and does so for all its chemistry courses. Two institutions, like WMU, treat the lab as a separate course. These institutions were a regional state institution and a liberal arts college. The unnamed university treats the lab as a separate course in Organic II, but not Organic I.

One regional state school, one liberal arts school, and one community college, like WMU, do not have a set laboratory book used. There seemed to be little standardization between the institutions that did require a published lab book; no two institutions use the same book. There seemed to be more standardization within lecture books used; WMU uses Klein’s Organic Chemistry text in the third edition. A regional state school and a liberal arts school also reported having used this text. One community college and one regional state school both reported using Solomons’ text, in the twelfth and eleventh editions, respectively. One liberal arts school reported using Wade’s text in the seventh, eighth, or ninth editions. One community college’s instructors use Bruice’s eighth edition text, one liberal arts school uses Carey and Giuliano’s text in eighth or ninth edition, and the unnamed institution uses the Jones fifth edition.

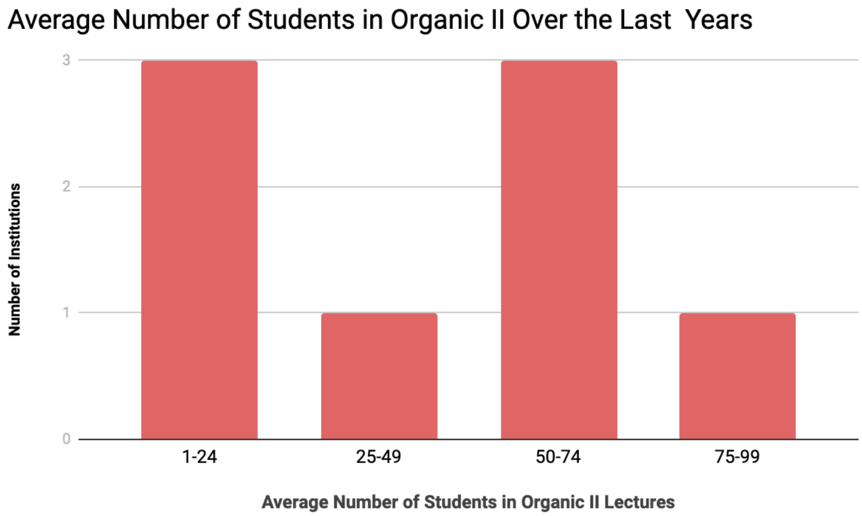
Figure 3: Average Class Size of Organic I Lectures in the Great

Lakes Region



WMU reported having an average class size between 100 and 149 students over the last five years, making WMU the institution with the largest number of students in its Organic I lecture. Most institutions surveyed, including two regional state institutions and a liberal arts college, keep their lecture between 50 and 74 students. Another liberal arts college and one community college reported their average class size for Organic I to be between 25 and 49 students. A liberal arts college and one community college reported having the smallest lecture class sizes; over the last five years, the number of students in the lecture were between 1 and 24. The unknown institution reported having between 75 and 99 students in an Organic I lecture. One institution, a community college, mentioned keeping a small classroom and teaching many sessions at once. The purpose of this is to keep lab classes under 20 people.

Figure 4: Average Class Size of Organic II Lectures in the Great Lakes Region



Institutions reported having much smaller classrooms in terms of the Organic II lecture. WMU reported an average class size, over the last five years, being between 75 and 99 students. Again, WMU reported having the largest class size of the eight schools surveyed. The unnamed institution, one regional state school, and one liberal arts school all reported Organic II lectures having between 50 and 74 students. A community college reported having between 25 and 49 students. Two liberal arts colleges and a community college all reported the smallest lecture class sizes, being between 1 and 24 students.

No placement tests were reported for Organic I between the eight schools surveyed. Most reported having a prerequisite of a “C” or higher in General Chemistry II. WMU also cited this requirement as the only prerequisite for Organic I, and the prerequisite of Organic II is a grade of “C” or better in Organic II. All schools reported that pre-professional majors, including pre-medicine, pharmacy, and veterinary students are required to take both courses.

Instructors at WMU Michigan do not use teaching assistants (TAs) in their lecture; TAs are solely in charge of the lab sessions. SIs have been made available to instructors over the years, but it is ultimately up to the professor as to whether SIs are implemented into their lecture. In more recent years, LAs have been used in place of SIs for Organic I; SIs are still used for Organic II. Other institutions, such as one regional state institution, also use SIs as a means of course assistance. They are expected to use active learning in their sessions, but not during lecture time. Two of the liberal arts institutions do not offer any out-of-class help for the courses. One liberal arts school, two community colleges, and one regional state institution offer drop-in tutoring.

WMU currently does not have an extra recitation hour for either of its organic chemistry classes. One regional state institution has an hour of recitation per week. Similarly, one liberal arts institution has an extra hour of lecture each week dedicated to problem-solving that is treated as a recitation hour. All other institutions reported no recitation hours.

Standardization

Most institutions, barring the unnamed institution, one liberal arts school, and one regional state institution attempt to keep the same instructor for the two-semester course. One liberal arts institution has only one teacher, and is thus able to keep the instructor consistent. All other universities surveyed noted that their department attempts to keep the same instructor, though this does not always work out. WMU was among these institutions. To ensure standardization between instructors, many institutions use the same textbook across all instructors and will cover the same chapters and material, but no school cited any sort of mandatory committee or meeting to ensure all professors cover the same material. WMU currently does not have anything in place to ensure standardization between instructors or the two courses; instructors voluntarily coordinate among themselves. It is important to note that the Student Success Services at WMU holds monthly meetings for a committee designed to better the overall DEWI rate, though participation in this committee is not mandatory (Student Success Services). In addition to this, no school surveyed had a standardized grade scale; all instructors set their own scale.

When asked about how often the curriculum is modified, one liberal arts institution and one state institution cited a requirement by their department every five to ten years to modify the curriculum as needed. One community college cited this occuring at the start of every semester, and other institutions leave this decision solely up to the instructor. Most instructors who are in the latter situation tend to evaluate the curriculum on their own as the see fit; roughly every five or so years.

Figure 5: Weight Distribution of Exams in Organic I and Organic II Courses

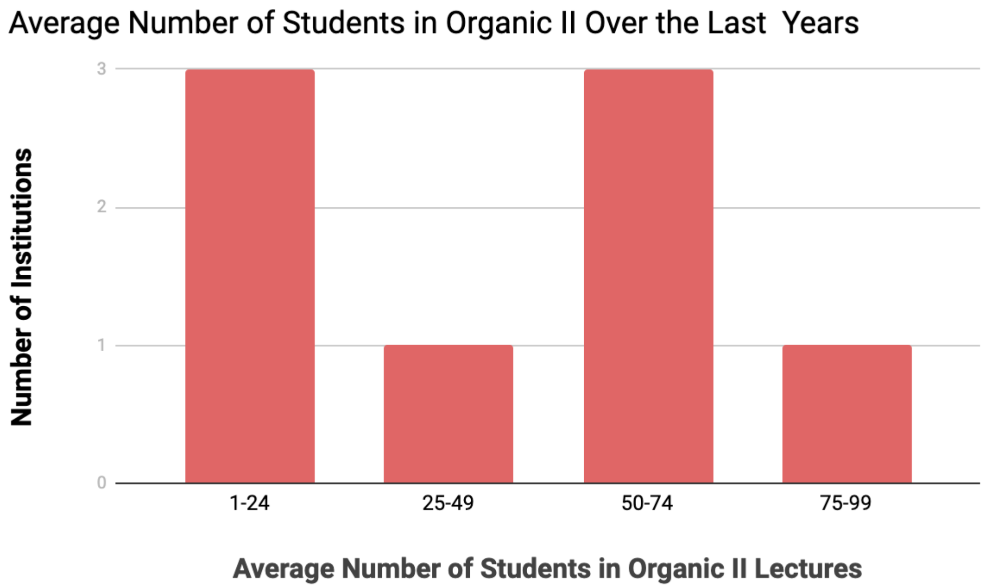
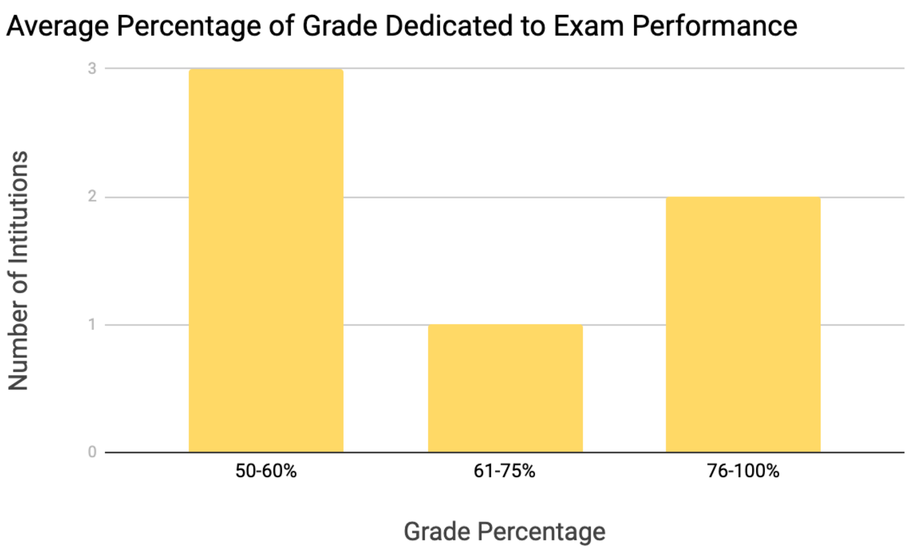


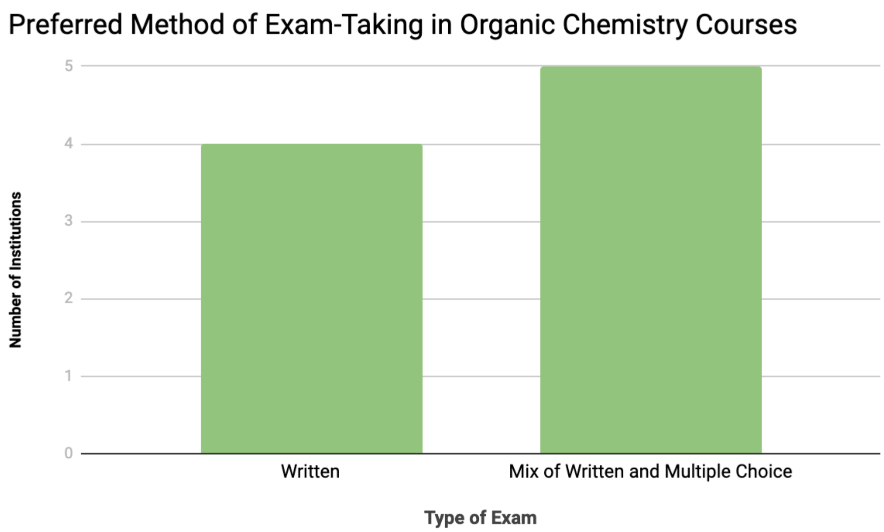
Figure 6: Average Percentage of Grade Dedicated to Exam Performance



When instructors were asked about their grade distribution, all instructors cited that their emphasis was on exams and the final, which encompassed more than half of the overall grade for every institution surveyed. WMU cited that roughly 80% of the grade is based upon exam performance. The institutions that include the lab within the lecture stated that 20%-30% of the overall grade is determined through lab performance. No institution surveyed valued their exams at less than 50% of the overall grade. The institutions that had the exams (including the final exam) encompass 75-95% of the overall grade included the unnamed institution, WMU, and one liberal arts institution. Institutions that valued the exams between 50-60% were two regional state institutions and one community college.

Six institutions, barring the unnamed institution and one liberal arts institution use homework as a portion of the overall grade. Homework was between 5-15% of the overall grade for all institutions.

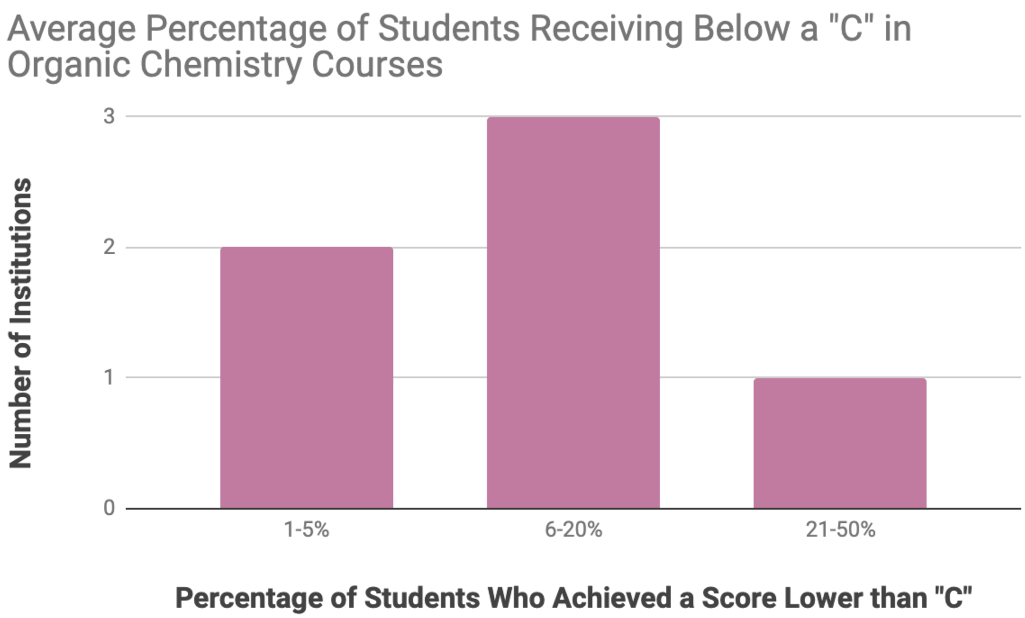
Figure 7: Preferred method of exam-taking in Organic I and Organic II



The general consensus between all instructors surveyed was that the best way for students to prepare for exams was through practicing. No schools surveyed reported using multiple choice as the preferred type of exam given; five institutions, including WMU, one regional state institution, two liberal arts institutions, and one community college cited using a mix of written and multiple choice problems. Four, including the unnamed institution, one community college, one regional state institution, and one liberal arts institution cited using strictly written exams.

Content and Outcomes

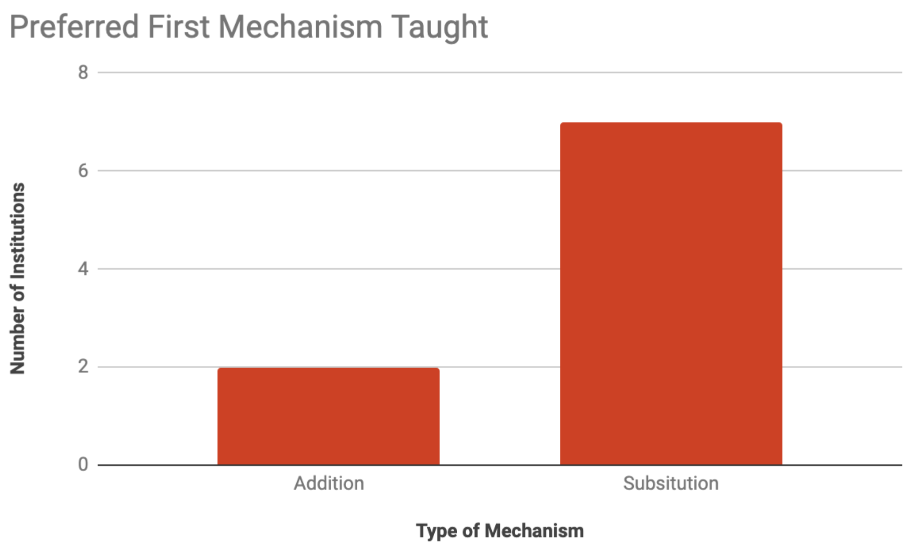
Figure 8: Average Fail Rates in Organic I and II



The official DEWI rate for WMU is 53.5% as of the 2017-2018 school year for Organic I and 36.9% for Organic II. Of the nine responses to the survey, this was the highest rate. Most schools gave a percentage between 5-30% of total students receiving a grade lower than a "C." The unnamed institution, one liberal arts institution, reported a fail rate of 2-5%. Two liberal arts institutions and one state institution reported a 10-15% fail rate. One regional state institution reported having a fail rate of 30%.

All instructors reporting having a preference in teaching from a mechanistic approach; that is, there is normally no emphasis on name-reactions, but rather, the mechanisms that encompass the named reaction.

Figure 9: Preferred First Mechanism Taught in Organic I



Institutions were asked about which common reaction mechanism is introduced first: addition to alkenes or substitution reactions. One community college stated that addition reactions are introduced first as they are viewed, in the eyes of the instructor, as easier to follow. A regional state institution also teaches addition first, as it is a good way, in the instructor's opinion, to introduce stereochemical outcomes of reactions. The other institutions, including WMU, the unnamed institution, one community college, three liberal arts institutions, and one regional state school, reported teaching substitution first. Reasons for this were given as it is how the textbook teaches them, it is easier to introduce the idea of stereochemistry, and it simply makes sense to the instructor to begin with these mechanisms, then later introduce addition reaction mechanisms.

Discussions

Course Structure

WMU uses a similar textbook and class arrangement as most schools in the Great Lakes region; however, it became clear that WMU's class sizes are far larger than the other institutions surveyed, even with the regional state institutions with a similar number of students enrolled. WMU, like the other institutions surveyed, do not require a placement test for their organic chemistry courses. In terms of outside-of-lecture help, WMU's use of the Student Success Services, SIs, and, more recently, LAs, seems to be ahead of the curve. Most institutions only cited having drop-in tutoring, though some did mention use of undergraduate TAs that are comparable to WMU's LA program. It can also be noted that WMU is in the majority of institutions that do not have an extra hour for recitation. However, it has been found that using LAs to hold recitation-like office hours encouraged students to ask questions and gain a better understanding of the difficult concepts taught in STEM courses (Schick 2018). Moreover, Ruder and Stanford found that using undergraduate TAs allowed for the instructor to be more flexible in terms of using an active-learning approach for a larger classroom (2008). The TAs also helped quickly identify where students were struggling, allowing for better understanding of the topics being taught. Adding undergraduate TAs who recently took the course may assist in the logistics of utilizing a nontraditional approach to larger classroom lectures such as organic chemistry. With WMU's use of LAs in this way, a recitation-like hour held by LAs worth a certain percentage of the students' grades could be easily implemented in the foreseeable future.

WMU's average class size was smaller for Organic II than it was Organic I, but it was still considerably higher than most institutions, who cited having anywhere between 1 and 74 students. Pursell et al. found that instructors that utilize the Thayer Method of teaching, which, like the flipped classroom method, is defined as instructors facilitating learning as opposed to leading, found it easier to facilitate learning in a smaller classroom (2012). Classroom size may attribute to better retention of concepts, though no conclusions may be drawn from this study. However, the idea of holding many sessions of one class with a much smaller number of students in each section may be something to explore in getting WMU's organic class sizes within the range of institutions comparable to WMU.

Most institutions surveyed reported their lab is incorporated into the lecture grade, though no conclusions can be drawn in terms of which course structure is more beneficial to students' understanding of organic chemistry, nor can any conclusions be made as to if having a 20-30% portion of the overall grade come from lab work being beneficial to students' understanding and success in the courses.

Standardization

WMU implements similar strategies of standardization between different instructors as other comparable institutions; most institutions attempt to maintain the same instructor for each cycle of Organic I and Organic II, though this cannot always be guaranteed. Though no conclusions can be drawn from this study, it is important to note that instructors surveyed mentioned coordinating with other members of their staff to ensure some standardization, and all instructors tend to cover the same chapters using the same book from the institution. There was also no report of any other institutions using a platform similar to Gateways to Completion for modifying the curriculum, and only two institutions cited having a mandatory meeting every five to ten years to evaluate the curriculum. The participants in this study mostly cited that the modification of the curriculum does not come from their department at all; it is solely up to the instructor to evaluate the course as needed.

In terms of weight distribution of both courses, no institution reported their exams and the final exam accounting for less than 50% of the overall course. WMU, in comparison to other schools surveyed, accounts for the majority of its grade (roughly 80%) in lecture grades. Only the unnamed institution accounted for a higher percentage, at 95% of the students' grades being determined by test performance. About 57% of the instructors surveyed keep the value of exams between 50-60% of the overall grade. It is important to note that some institutions include the lecture with the lab, which accounts for about 20-30% of the students' grade, and WMU keeps its lab as a separate, one credit course. This factor could have an influence as to how much weight the exams are awarded at each institution and must be considered when interpreting these data. In addition to this, the use of homework between institutions was relatively similar; all institutions except for two cited dedicating some percentage of overall grades (between 5-15%) for homework. Per Parker and Loudon, it was found that students' retention and grades may improve with use of online homework, especially in large classroom settings (2013). If it is not possible to have smaller lecture sizes at WMU, perhaps an emphasis on doing homework and dedication to more of the overall grade going to homework performance may improve the DEWI rate.

Though no conclusions can be drawn from this, it is important to note that no schools surveyed use strictly multiple choice, despite some institutions - including WMU - having large class sizes. Five institutions reported using a mix of multiple choice and written problems. If grading is a concern with written exams, perhaps hiring undergraduate graders with strict keys to follow for grading may relieve some of the stress placed upon instructors to grade in a timely fashion.

Content and Outcomes

Despite having similar practices to its regional counterparts, WMU has a DEWI rate for Organic I that is staggeringly higher than the institutions. Per Gateways to Completion, the DEWI rate for WMU is 53.5%. Institutions of similar sizes to WMU reported having a fail rate between 15% and 30%. Because it was not specified within answers, it is difficult to say whether the numbers given were for Organic I or Organic II. In the future, this question should be split into two different questions, one to ask for the DEWI rates of either class. However, even when comparing the numbers given with both WMU's DEWI rates for Organic I and Organic II, the numbers given are much higher than other institutions reported. The Organic II DEWI rate for WMU is 36.9%; almost 7% higher than the highest report from institutions comparable to WMU. There is a correlation, based on the data collected, between class size and fail rate; the regional state institution reporting a 30% fail rate cited an average class size between 50-74 students for Organic I lectures and Organic II. Though still not as large as the class size at WMU, this number is on the high end of reported class sizes. Though this does not necessarily mean causation, it may be said that smaller class sizes, as discussed previously, allow for easier implementation of active learning strategies proven to increase student success rate (Pursell 2012).

Some standardization was noted within the method of teaching reaction schemes to students. All instructors reported preferring to focus heavily upon mechanisms rather than “name reactions” such as the Williamson ether synthesis. Moreover, seven of the nine instructors reported preferring to teach substitution reactions first, then addition reactions. WMU was among these seven institutions. The reasons given were all similar, as well; most cited it was due to the textbook used and simply because it made the most sense to the instructor; some reported substitution reactions being an easy way to introduce some of the core concepts of organic chemistry, including stereochemistry, arrow-pushing, and the role of electron density in molecular interactions. The curriculum from each institution is generally standardized; this could be due to most of the institutions surveyed (excluding community colleges) being ACS accredited.

Summaries

WMU is similar to its Great Lakes counterparts; it, like most other institutions surveyed, teaches in a lecture-setting with a large class size, which is then separated into smaller lab sections run by TAs, where instructors have little to no influence. The curriculum taught is generally the same; similar textbooks and similar styles of teaching are shared among the institutions surveyed. This could be due most institutions surveyed being ACS accredited; though community colleges surveyed were not ACS accredited, many of these institutions have curricula created with students who plan to transfer to other higher education institutions in mind, which could explain why the curricula of these schools is so similar to other higher education institutions.

The general format of grading also appears to be the same; all institutions allow the instructor to set the grade scale and determine how these grades are weighted. While it is important to allow each instructor to lecture as they see fit, at what cost does this lack of standardization between instructors have for the student? Can a student who achieved an “A” with one instructor at one institution anticipate that, with the same amount of studying and same general structure of the course, they will achieve an “A” with a different instructor? How would the instructors of both courses and the students react to a department-set grade scale? It is a difficult question to answer; it is important that each instructor teach as they want, with certain components dedicated to each percentage of the overall grade as the instructor sees fit. Where does this consideration end and the need for standardization begin?

With this question in mind, the idea of a meeting to discuss curriculum changes may be the answer. Though WMU's Student Success Services currently has a committee for each high DEWI-rate class to discuss potential changes to the curriculum, participation is optional. Perhaps a department committee, similar to one the Student Success Services uses, that meets at the beginning and end of each semester to discuss how to improve student success could benefit both instructors and future students by implementing smaller changes each semester as seen fit. In this way, instructors could collaborate to ensure that an "A" student remains an "A" student regardless of the instructor changing between the two courses.

This study also brings up a valid problem that seems to be prevalent in all aspects of higher education: how does one define success? In this study, success was defined as achieving an overall grade of a "C" or better; however, is this truly the best way to define success? If this study were to be repeated, a subsection of questions regarding success should be added, and may look similar to the subsection outlined in the revised survey below.

Another problem this study often ran into is finding the balance between asking the right amount of questions without discouraging instructors from responding with the sheer amount of time it takes to respond. No questions in this survey were required, except for the identifying questions regarding the institution the instructor taught at as well as an email. If this study were to be conducted again, a survey similar to the one outlined below should be considered:

Figure 10: Revised Google Form Survey

Course Structure: The set of questions below are concerned with the overall structure of both courses.

1. Is the lab a portion of the lecture grade, or is the lab a separate course?
2. How involved are you in the lab? Who determines the lab grades?

3. What lab book is required for both courses? Is this book used for both labs?
4. What textbook and edition of the book is used in both courses?
5. What is the average class size over the last five years for Organic I?
    a. 1-24
    b. 25-49
    c. 50-74
    d. 75-99
    e. 100-149
    f. 150-199
    g. 200-249
    h. 250+
6. What is the average class size over the last five years for Organic II?
    a. 1-24
    b. 25-49
    c. 50-74
    d. 75-99
    e. 100-149
    f. 150-199
    g. 200-249
    h. 250+
7. What are the prerequisites of Organic I? Are there any placement tests, or are students only expected to pass the prerequisite(s)?
8. Are there TAs involved in the lecture?
9. What type of supplemental instruction (learning assistants, SI leaders, tutoring) is offered for both courses?
10. Is there a recitation time offered in the course? If so, how much time per week?

Standardization: The questions in the following section are concerned with how your department standardizes both courses across semesters and instructors.

1. As a matter of policy, do you try to keep the same instructor for the second semester follow-up course?
2. If the two courses are taught by different instructors, how does the department ensure standardization between different instructors?
3. Is the grading standardized by the department? If not, who sets the grade scale?
4. What are the required components of an overall course grade? How are they weighted?
5. What overall grade percentage must a student earn to achieve a "C" in your Organic I course?
6. What overall grade percentage must a student earn to achieve a "C" in your Organic II course?
7. Why do you set your grade scale as you do? That is, if a student must earn a 92% in your class to achieve an overall letter grade of "A," what made you decide upon this percentage?
8. Are exams multiple choice, written, or a mix?
    a. Multiple choice
    b. Written
    c. Mix
9. How often do instructors get together to talk about modifying the curriculum? Does your institution provide resources for that evaluation?

Content, outcomes, and success: The following set of questions concern themselves with the content and end goals of both courses.

1. Do you prefer to teach addition reactions or substitution reactions first, and why?
2. How much emphasis is put on learning name reactions vs. mechanisms? E.g. Williamson Ether reaction is taught as an Sn2 reaction.
3. If you are willing to share, what is the approximate number of students who score lower than a C for Organic I?

4. What is the approximate number of students who score lower than a C for Organic II?
5. In your opinion, what defines a "successful student?"
6. Do you believe having the lab grade as a percentage of the lecture grade helps or hinders your students in terms of overall success in the course? Why or why not?
7. Is there anything else you'd like to tell me regarding Organic I and II?
8. Would you mind if I contacted you to ask follow-up questions to strengthen my thesis? What is the best way to reach you?

The large class size, high DEWI rate, and amount of the overall grade awarded to exam-performance is what unfortunately sets WMU apart from the other institutions surveyed. All institutions surveyed, with the exception of the community colleges, are ACS accredited, and thus adhere to the suggested curriculum from the ACS for either course. Therefore, it is not surprising that the institutions surveyed reported having similar teaching preferences and expectations of their students. Given that these important portions of the two classes are seemingly standardized, the only differences that can possibly explain WMU's high DEWI rate is the number of students per class and the amount of the overall grade dedicated to exam performance. Though this study was not extensive enough to draw conclusions upon, perhaps considering offering more sections of the course per semester and lowering the weight of exam grades might show an overall decrease in the DEWI rates for both Organic I and Organic II.

However, these changes may place stress on instructors; not all instructors solely teach organic chemistry, and thus might not have the time or means to hold more than one section of an organic chemistry lecture per semester. Moreover, WMU's chemistry department does not set the grade scale for the Organic I or II classes; instructors would have to agree among themselves to lower the weight exams have on students' grades. In addition to this, perhaps exams are the best way to determine student success; if this is the case, is it right of WMU to place so much value in exam performance? The answer to these questions lie beyond the scope of this study and cannot be determined from this study alone.

The aim of this study was to determine the best organic chemistry practices in the Great Lakes States, and how WMU's student success rates in Organic I and II compare to similar institutions in the

Great Lakes regions. Class size, the incorporation of the lab in the lecture grade, and standardization within the grade scale of an institution might help realize a lower DEWI rate. Though the hypotheses stated cannot be proven given this study, important observations were made in terms of how these factors differ between the different types of institutions surveyed. Insufficient data were collected to determine whether there was any standardization between the different types of institutions surveyed, and further testing would have to be conducted to determine if this hypothesis should be accepted.

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