Andrews University
Department of Chemistry & Biochemistry
Self-Study

Submitted by the
Department of Chemistry
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CRITERION 1: Mission, History, Impact, and Demand

1. How does the program contribute to the mission of Andrews University and the Seventh-day Adventist Church?

The mission statement of the Department of Chemistry & Biochemistry within the context of Andrews University and the Seventh-day Adventist Church is:

1. To ***assist*** all students to excel in developing their analytical and critical reasoning skills, using fundamental chemical principles and computational methods,

2. To ***prepare*** our chemistry and biochemistry majors to enter graduate school, professional school, the chemical industry, or the teaching profession, in a diverse world,

3. To ***develop*** in our students an understanding of responsible, environmentally sensitive use of global resources,

4. To ***engage*** students and faculty in the process of discovery and creativity in the research lab and the classroom, and

5. To ***model*** a life of personal and professional integrity.

The mission and vision of Andrews University is encapsulated in its motto “seek knowledge, affirm faith and change the world.” Embedded in this statement is the distinctive Seventh-day Adventist philosophy of education as redemption, as stated in the book *Education*, “In the highest sense the work of education and the work of redemption are one …” Indeed, 1 Corinthians 3:9 states that, “we are laborers together with God …”

Within this context the Andrews University Department of Chemistry & Biochemistry interprets redemption not only as personal but also as material and environmental. Redemption is not limited to personal spiritual transformation but also embodies transformation of our material world for the glory of God and the benefit of all humanity. Indeed, we are in effect called to be co-workers and co-creators in transforming the world.

Chemistry is if nothing else, the transformative science. The two most fundamental questions of chemistry involve *identity* and *change*: *What is it*? and *What can it become*? At its very core is the concept and reality of change, physical and chemical. Of all the sciences, chemistry and its principles are most easily appropriated as metaphors for identity and change. So, the five elements of our department’s mission statement bears witness to and are consistent with the deepest levels of the transformative and redemptive nature of education.

2. How does the history of the program define its contributions to Andrews University?

History of the Department of Chemistry & Biochemistry

1874

The first chemistry course offered at Battle Creek College was taught by John Harvey Kellogg, MD. It focused on practical chemistry, such as, the chemical effects of light, and chemistry of the atmosphere, water and food. Tuition for the 12-week term was between three and six dollars.

1901

Sanford P. S. Edwards, MD taught the first chemistry course at Emmanuel Missionary College (EMC). He taught from 1901–1903. For the next two decades Olen R. Cooper, MD taught chemistry.

1929

Under the capable leadership of Reu E. Hoen, who received a PhD from the University of Chicago, the Science Hall was built and occupied in 1932. Hoen was professor of science and mathematics from 1929–1937.

1937

Herwarth F. Halenz, with a PhD in biochemistry from University of Colorado, joined the faculty in 1937. The major in chemistry was first offered under the Department of Physical Science and Mathematics. The subjects taught for the chemistry major were: General Chemistry, Organic Chemistry, Qualitative and Quantitative Analysis, and Physical Chemistry.

Henry J Klooster, EMC President 1937–1943, was an MS Chemist, and taught chemistry.

1940

The Department of Chemistry, housed in Science Hall, was formed with Dr Herwarth F. Halenz as the first chair. In 1940, three students graduated with BAs in Chemistry and all pursued careers in medicine. For the next two decades, most chemistry graduates entered the medical profession; a few went into research or teaching.

1950

The Departments of Chemistry and Physics combined until 1954.

1960

Douglas Brown was chair from 1960–61 and H. F. Halenz returned as interim chair 1961–62.

1962

Dwain L. Ford, PhD, chaired the department from 1962–71 and began to focus the department on the preparation of professional chemists. Under his skillful guidance: (1) plans were drawn for a new science building, (2) a glassblowing course was offered, (3) the Seminar in Chemistry began in 1965 and the Seminar Guest Speaker Lecture Series began in 1971, (4) the BS degree in Chemistry started in 1967, and (5) the Berrien County Drug Identification Center was established in conjunction with Berrien County in 1971 with Lloyd Kuhn as the first forensic analyst. In 1968 Aida Weiss, the first female chemistry teacher was hired. The first BS Chemistry graduate was Richard Hannon in 1970.

1971

Robert A. Wilkins, PhD became chair of the department from 1971–88. He coordinated the department's application for American Chemical Society (ACS) approval for the training of professional chemists. In 1972 the chemistry department was the first to enter the new Science Complex. In 1974 the department had five professors all with PhD degrees and equipment grants placed the department in a good position for ACS approval. In 1976 the department was granted ACS approval and remains the only SDA college/university to attain this approval. In 1979 the BS in Biochemistry was offered as a track to prepare students for medical school. In 1980 the department began a concerted effort to establish relationships with industry and permit students to obtain internships and coops. Over 100 chemistry and biochemistry students have benefited from this program. In 1984 the Dow Scholarship program was inaugurated for students pursuing a career in chemical research.

1988

G. William Mutch chaired the department from 1988-2008. More students were entering professional chemistry careers. In 1995 the department was renamed the Department of Chemistry & Biochemistry. In 2000 the 400 MHz NMR instrument was acquired and interfaced with Southwestern Michigan College and Lake Michigan College. Dr. Desmond Murray introduced early research initiatives for high school and college students and course-based undergraduate research experiences in 1998. The first (and to date only) major external research grants were obtained by Dr. Desmond Murray in 2003 from the National Science Foundation and the American Chemical Society Petroleum Research Fund. Faculty research, student research, and instrument acquisition increased; student research posters and talks increased at on-campus and off-campus venues.

2008

David Nowack was named chair of the department in 2008. In 2009, using the Andrews University Biochemistry degree as a foundation, a second, more rigorous and ACS-approved Biochemistry degree was developed and implemented. A major 3-year renovation of the department stockrooms, laboratories and hood system was completed in 2013. Faculty and student research continues to increase.

Contributions of the Department of Chemistry & Biochemistry to Andrews University

From the above history, it is evident that chemistry, the subject and the department, has played and made significant contributions to Andrews University. Long before our formal organization as a department 75 years ago in 1940, Dr. John Harvey Kellogg offered chemistry courses at Battle Creek College in 1874.

The professionalization of the chemistry instructional staff at Battle Creek College—Emmanuel Missionary College—Andrews University parallels the broader history of science professionalization across the United States. Significant milestones in the professionalization of science in the United States occurred when Yale University granted the first science-engineering PhD to Josiah Willard Gibbs in 1863 and Harvard awarded its first chemistry PhD in 1877. By the 1880s, the professionalization of chemistry was well on its way with the establishment of the American Chemical Society in 1876; the launch of journals such as Journal of the American Chemical Society in 1879; the growth of chemistry departments across the United States; the founding of major science-focused universities, such as, Massachusetts Institute of Technology MIT in 1861 and John Hopkins in 1876 as the first American research university.

Thus, our early instructional staff in chemistry did not have professional degrees in chemistry: John Harvey Kellogg, MD, Sanford P. S. Edwards MD, Joseph H Haughey, and Olen R Cooper MD, did not hold advanced degrees in chemistry.

The first faculty with a PhD in Chemistry was Reu E. Hoen, 1929–1937, played a leadership role in the construction of the Science Hall – the first building dedicated to the sciences – in 1932. Later on, Henry J Klooster, EMC President from 1937–1943, an MS Chemist, also taught chemistry. By 1971 all teaching faculty in the department held PhD degrees in Chemistry.

Another significant trend in the history and contribution of the department to the university was the focus of preparing students for the health and medical professions. Most of the graduates from the department entered into these professions. However, beginning in 1976 with ACS approval of our BS degree, a greater percentage of our department graduates entered the chemistry profession usually after completing their PhD degrees in graduate schools across the United States. Today, the department continues to serve students seeking to enter the health and medical fields particularly through our General Chemistry, Organic Chemistry and Biochemistry courses.

Given our history and as the first and only ACS approved Department of Chemistry and Biochemistry, our department holds the distinction of serving as a first-degree training ground for a significant number of other SDA college chemistry departments across the United States.

3. How does the program contribute to the academic success of Andrews University?

Several aspects of our program distinctively contribute to the academic success of Andrews University students and to the university as a whole: American Chemical Society (ACS) approval, service courses, partnership with Berrien County Regional Educational Service Agency (RESA), departmental seminar program, Berrien County Forensic Lab, and Early Research.

American Chemical Society Approval

Thirty-six years after official formation as a department in 1940, under the leadership of Dr. Robert Wilkins, our department secured program approval for our BS Chemistry degree in 1976 from the American Chemical Society. Later on in 2009 under the leadership of Dr. David Nowack we also secured ACS approval for our BS Biochemistry degree. The ACS (https://www.acs.org) is the largest scientific organization in the world. Andrews University is the only Seventh-day Adventist university with ACS approved degrees.

The ACS approved degrees position our graduates for entrance into chemistry and biochemistry graduate programs at any institution across the United States, and provide our students with the security and that ACS approval brings in the marketplace, offering them a competitive advantage over graduates from other SDA college chemistry departments.

Service Courses

Over the years the department has contributed to the academic success of thousands of students and to Andrews University through its offerings of service courses. These are courses needed by non-chemistry majors to complete their degree requirements. Our core service courses include Consumer Chemistry (CHEM100), Introduction to Inorganic and Organic Chemistry (CHEM110), Introduction to Biochemistry (BCHM120), General Chemistry (CHEM131, 132), Organic Chemistry (CHEM231, 232, 241, 242) and Biochemistry (BCHM421). All of these core service courses routinely and consistently have upwards of 85% or more non-chemistry majors. Students taking these courses belong to other university departments, such as, Biology, Physics, Engineering, Medical Laboratory Sciences, Behavioral Sciences, Physical Therapy and Nursing. A very significant number of these students are PreMed, PreDent and PrePharmacy students. The 100 level chemistry courses are also taken by some students to fulfill their general education requirements.

Other courses that are open to qualified non-majors are: Independent Research (CHEM195, 295, 495), Forensic Chemistry (CHEM410), and Laboratory Glassblowing (CHEM300). These courses generally have much smaller class sizes but provide the interested student significant additional academic, technical and market value that can enhance their competitiveness in graduate school, medical school, another professional program or in the workplace.

Partnership with Berrien County RESA

The Berrien County Mathematics & Science Center (BCMSC) was created and established in 1991 to challenge and inspire high school students in the local communities surrounding Andrews University. During this 25-year period, the Department of Chemistry & Biochemistry has played a major and distinctive role in this partnership between Andrews University and Berrien County RESA.

Some distinguishing contributions from our department include:

- using our PhD degreed faculty as sole instructors for Grade 10 and Grade 12 chemistry (other departments have used non-PhD staff),
- providing full access of departmental resources, materials, supplies, laboratory space, and instrumentation for BCMSC Grade 10 and Grade 12,
- complete overhauling of Grade 12 chemistry from a traditional course into a research-based course,
- offering college credit (CHEM195) for Grade 12 chemistry students that satisfactorily completes their research project,
- initiating, collaborating, and implementing, with the Biology Department, a seamless year of research for BCMSC Grade 12 students,
- offering summer research opportunities (some paid) for BCMSC students, and
- cooperating with Berrien RESA in organizing and implementing an annual Research Symposium for high schools students throughout southwest Michigan and Northern Indiana. RESA's annual symposium was pre-dated by the annual BEST Early Research Symposium that was solely designed and implemented by one of our faculty, Dr. Desmond Murray for about five years. This overall effort, in part, led to Murray receiving the 2012 Science Teacher of the Year Award by Michigan Science Teachers Association.

In addition to the value added for BCMSC and its students, many of our college majors benefit from being employed as teaching and lab assistants for BCMSC Grade 10 and Grade 12 courses. This also provides them an opportunity to deepen their understanding and application of chemistry concepts and contributes to their academic success.

Seminar Program, Public Science and Department Visibility

A major distinctive feature of our department is its Seminar program. It provides incalculable value to student, department and the university. A description of our program was published in the Journal of Chemical Education (J. Chem. Educ., 2011, 88 (8), pp 1085–1089) in 2011.

History and background of the seminar program

The seminar program of the Andrews University Department of Chemistry and Biochemistry began in 1965 by former professor and department chair, Dr. Dwain L. Ford. It was originally designed to provide our upperclassmen with the soft skills of science communication, oral and written. Today it has evolved to a multipurpose four-year, two-credit sequence that engages all our majors, freshmen to seniors, in science communication and provides them with the following additional benefits:

- Staying up-to-date, fresh and current in (bio)chemistry,
- Networking with a diversity of science professionals, academic and non-academic,
- Developing scientific (and patent) literature searching skills,
- Finding paid summer research opportunities,
- Learning how to prepare and deliver scientific talks (three talks required),
- Receiving advice on being a successful professional,
- Thinking critically about current issues and advances in (bio)chemistry,

- Discovering possible professional interests and careers,
- Increasing awareness about the (bio)chemistry profession and available resources,
- Evaluating multiple communication skills and styles, and
- Developing resume-writing and job interviewing skills.

Facilitated by modern communication technology, our seminar program also regularly features guest lecturers from around the United States, giving in-person or online (webinar) presentations. Our records indicate over 260 guest lectures since the 2000 – 2001 school year. There is an average of about 8 - 10 guest speakers each semester. As part of our 50th year celebrations of our seminar program, we re-named the guest speaker series, which had begun in 1971, the Dwain L Ford Lecture Series, and is currently co-sponsored by Andrews University Office of Scholarly & Creative Research. The series provides students, faculty and the wider community an opportunity to hear guest speakers from academia, industry and government present topics of current interest and importance in chemistry and chemistry-related fields.

Seminar program promotes department visibility and public science

One of the key transformations of our seminar program over the last two decades is its increasing and intentional public visibility. Using basic modern communication tools, such as, email, webinars, You Tube, social media and print media, our seminar program now reaches far beyond the confines of the Chemistry Amphitheatre. Public science is an intentional aspect of our program that engages the public in topics of interest, that may come directly from the news. For example, we invited guest speakers to talk about the science(chemistry) behind the BP Oil Spill, Ebola, EPA Gold Mining Spill, and the Flint Water Lead Poisoning Crisis. In all of these cases, in addition to public announcements, the guest lectures were covered and published in local media, in hardcopy and online. We believe that our enhanced public visibility and online accessibility can serve as a component of our departmental recruiting efforts.

Seminar program webinar

We introduced the practice of webinar-based guest presentations in the 2011-2012 academic school year. Here are a few webinar highlights.

Brad Tait, *PTI*, *Cambridge, MA*, The Science of Proteostasis, **2011**
Ivan Oransky, *New York University*, Retractions and Scientific Transparency, **2014**
Jenelle Lynn Ball, *Chico High School*, *California*, Teaching High School Chemistry, **2016**

As the above list shows the integration of webinars into our seminar program removes a lot of barriers (geographical distance, time, cost, convenience) that would otherwise be in play if we tried securing the above speakers by the traditional seminar approach. It also provides us with a limitless pool of guest speakers to choose from. This is good for our students, faculty and for the wider university and serves to increase our overall academic climate, student interest and success.

Community Engagement

A longstanding and significant contribution of the department to the university and local community is the Berrien County Forensic Lab. Under the leadership of Dr. Dwain L Ford, the Berrien County Drug I.D. Center was established in conjunction with Berrien County in 1971 with Lloyd Kuhn as the first forensic analyst.

The Berrien County Forensic Laboratory (BCFL), sponsored by the Berrien County Prosecutor's Office and housed within and staffed by the Chemistry Department, underwent a re-organization in 2010. BCFL continues to support law enforcement with analytical reports and court testimony regarding violations of the Controlled Substance Act. Instrumental analysis is augmented by a time-of-flight gas chromatograph/mass spectrometer leased through local vendor LECO Corporation.

The forensic lab director teaches Forensic Chemistry (CHEM410) and mentors students presenting relevant topics for Chemistry Seminar. The local community benefits by BCFL serving as a transporter of discarded medications from municipal collection sites. These are included in the biannual destruction of litigated evidence which amounts to more than 3000 pounds annually. The lab director has been hosted by several school classrooms and civic organizations to present on trends in drug abuse.

Our Forensic Chemistry course has inspired a few of our students to pursue and excel in careers in this important field. In fact, two of BCFL directors, Dale Gooden (1983 - 1988) and John Rorabeck (2010 – present) had their start in CHEM410. Therefore, the Forensic Chemistry lab and course contribute to the academic success and career choices of our majors and also to the department's engagement with the local community.

Public Science

For the last four years, Dr. Ahlberg has taught several mini-courses in kitchen chemistry for students at Ruth Murdoch Elementary School. In addition, Drs. Ahlberg, Randall, Nowack and Hayes have provided chemistry demos and object lessons to area churches and youth groups (Pathfinders, etc.). These demos also engage undergraduate students in learning, leadership and service.

Early Research

Another area of contribution of the department to the academic success of Andrews University is its engagement of high school and early college students in authentic research. This roughly 20-year effort in early research effort has led to:

1. Development of CHEM 195 and CHEM 295 Independent Research courses,
2. Development of Course-based Undergraduate Research Experiences (CURES),
3. Engagement of over 1,000 students in authentic research,
4. Over $750,000 in grants (external and internal) to the department,
5. Purchase of materials, supplies and instrumentation for the department,
6. Collaboration with Benton Harbor Area Schools to provide research opportunities for students (http://www.bhas.org/domain/330),
7. Recognition by the state of Michigan,
8. Affirmative mention in ACS review of our program,
9. Imminent publication (in 2016) of an ACS Symposium Series Book.

4. What is program enrollment and state of demand for graduates of the program?

Program Enrollment

The program enrollment for the Department of Chemistry & Biochemistry has remained fairly steady over the last seven years. The numbers listed below are the total numbers of chemistry and biochemistry majors registered for the fall semesters of the years listed.

Fall	**Majors**
2016-17	42
2015-16	49
2014-15	44
2013-14	43
2012-13	39
2011-12	39
2010-11	41

The lack of variability in the number of majors is in contrast to the experience of some other STEM departments that have wide variations in their enrollments. Oddly, the number is steady even in years that had significant extra recruiting efforts by the faculty.

General Employment Status

The demand (employment) for our program graduates can be viewed through the perspective of the general employment status of our field and the employment status of our graduates.

A high percentage of chemistry/biochemistry graduates pursue graduate or professional degrees immediately after earning their bachelor's degree. Eighty present of chemistry/biochemistry graduates who applied to medical school from 2010–2015 were accepted, 1.8 times the national average, and more than 90% of those who apply to graduate programs are admitted.

Employment data for persons trained in chemical skill-relate occupations remain strong and rising. For example, the U.S. Bureau of Labor Statistics Occupational Outlook Handbook (http://www.bls.gov/ooh) projects an average growth rate of 7% for all life-phsyical-social science occupations between 2014 and 2024. **Table 1**: Employment data for selected professions chosen by chemistry graduates in the US. **Table 1** summarizes the latest available (May 2014) United States government employment data for professions that employ many of our graduates. **Table** 1 excludes academic careers and those requiring an MD degree. These are the latest available data from the U.S. Bureau of Labor Statistics, Occupational and Employment and Wages, May 2014 (www.bls.gov/ooh).

Table 1: Employment data for selected professions chosen by chemistry graduates in the US.

Job title	# of jobs in 2014	Anticipated growth 2014-24 (avg growth for all jobs: 5-8%)
Chemists/Material Scientists	98,400	3%
Chemical Technicians	66,500	2%
Pharmacists	297,000	3%
Agricultural/Food Scientists	33,000	5%
Biochemists/Biophysicists	34,100	8%
Medical Scientists/Researcher	107,900	8%
Environmental Science Technician	36,200	9%
Geoscientists	36,400	10%
Forensic Science Technician	14,400	27%

The demand for graduates from this program will remain as strong as other professions. Those graduates with a willingness to enter some of the more niche industries can expect higher employability. The upper level offerings within this program provides skills and knowledge useful in some of these lesser-entered job markets. The development of more and diverse internship opportunities would also enhance the resumes of our graduates

Program Graduates Employment Status

In the years 2010 to 2015, the Department of Chemistry & Biochemistry produced 42 graduates. Of those, nine were chemistry majors and 33 were biochemistry majors. Of the 42 graduates, sixteen have entered the medical field as enrollees in medical school, dental school, pharmacy school or physician's assistant school. Seventeen are working in industry or are actively pursuing graduate degrees in a variety of graduate programs. We do not currently know the status of nine of these 42 graduates. Thus, nearly 79% of our graduates in the last five years are known to have a job or are in graduate schools. Of those who are known to have jobs, about 60% are in chemistry-related fields.

CRITERION 2: Program Quality

5. Describe how the available human and physical resources relate to what is necessary to have a strong program of high quality that mentors students to succeed.

Human Resources

Table 2 summarizes the qualifications of our facility. All six full-time faculty members have a PhD in chemistry or biochemistry. A PhD is the terminal degree in our discipline.

Table 2: Faculty qualifications.

	PhD institution	Year of PhD completion	AU Faculty Since
David Nowack, PhD	Purdue University	1988	1998
Lisa Ahlberg, PhD	University of California, Davis	1997	2010
Ryan Hayes, PhD	Northwestern University	2002	2009
Getahun Merga, PhD	University of Pune, India.	1995	2002
Desmond Murray, PhD	Wayne State University	1995	1995
David Randall, PhD	University of California, Davis	1996	2009

With one exception, full-time faculty members lead all CHEM and BCHM courses, from our non-majors Gen Ed courses through our most advanced upper division chemistry course. The exception is CHEM410 Forensic Chemistry, which is taught by the chief analyst for the Berrien County Forensic Laboratory (BCFL), Mr. John Rorabeck, who has a master's degree and decades of experience in this field. This course is an upper-division elective course.

Student workers are valuable team members who support the faculty in several ways including serving as TAs, readers, and stockroom workers. While the exact criteria for student workers varies between faculty and job function, student workers are selected for their ability to represent the department well and exhibit traits such as curricular competence, enthusiasm, and service mentality. A lab room for General Chemistry might serve 20-30 students with one or two student TAs. To be sure, the PhD faculty instructor is also present and interacting with students. Student evaluations about labs do not negatively comment on staffing levels. The department has recently implemented a "6P" program to highlight clearly our expectations for TAs: excellent TAs are Punctual, Prepared, Pleasing, Proactive, Proficient, and Professional.

Student access to faculty mentoring

Our department teaches three high-enrollment courses: General Chemistry (2 sections), Organic Chemistry, and Biochemistry. Enrollment in each section is approximately 50-70 students. While these are not intimate classes, the instructors find opportunity to interact with and get to know individual students. Certainly, students who want to be known are known to faculty. Further, our faculty may target students in need of mentoring. The labs associated with courses also allow for more direct, informal interactions with students taking the courses and with students serving as TAs.

Physical Resources

The Department of Chemistry & Biochemistry is housed on all three floors of Halenz Hall in the science complex on the main campus of Andrews University. Halenz Hall was the first of the science complex halls to be completed in 1972. The building is very structurally sound which benefits sensitive measurements, such as accurate weighing samples (formally, obtaining the mass). Chemistry faculty at the time had input into the design of the building. All three floors of the building are shared with the Medical Lab Science program from the School of Health Professions.

Chemistry and biochemistry are somewhat unique because the atoms and molecules that we study are impossible to visually observe—even with microscopes. Accordingly for us to study molecules we must use instruments that help us to "see" the substances we study. These instruments are often complex in design and need specialized facilities. Further, some of the materials we use require special handling so that students, faculty and the environment can be safe. The best practices for safe handling of chemicals have evolved in the decades since the building was first constructed.

Teaching lab rooms

Chemistry and biochemistry laboratories are highly specialized spaces that contain fume hoods; lockers for students to store lab equipment; sinks; work surfaces that become contaminated with chemicals; and complex experimental setups which need to be left unchanged for days or weeks. The department has five rooms used for teaching labs: HH220, HH221, HH215, HH324, and HH325. **Table 3** below summarizes the utilization of our lab rooms. Our instrumentation rooms, HH123 and HH116 (NMR) are used both for teaching and for research.

Table 3: Utilization of our lab rooms; X indicates lab is in use.

Room	Area (ft^2)	Student Capacity	Fume Hoods	Fall	Spring	Summer	Sections per semester	Classes utilizing room
HH220	1660	30 students	5 hoods 29 feet	X X	X X		2 1	1. General Chemistry (C131,2) 2. Intro sequence (C110, B120)
HH221	1660	30 students	5 hoods 29 feet	X X X	X X X X	 X	2 1 1 2	1. General Chemistry (C131,2) 2. Intro sequence (C110, B120) 3. Consumer Chemistry (C100) 4. Grade 10 Chemistry (RESA)

HH215	1817	24 students	2 hoods 5+6 feet	X X X	 X X X		2 2 1 (R)	1. Quantitative Analysis (C200) 2. General Chemistry (C131,2) 3. Biochemistry Lab (B430) 4. Research space for Dr. Merga
HH324	1660	18 students	10 hoods 57 feet	X X X	X X X X	 X	2 2 1 Na 2 3 (equiv)	1. Organic Chemistry (C241,2) 2. Grade 12 (RESA) lecture 3. Chemical Separations (C400) 4. Research overflow, Dr. Murray 5. Quantitative Anal. (C200) lecture 6. Consumer Chem (C100) lecture
HH325	1660	18 students	10 hoods 57 feet	X X	X X X		2 2 na	1. Organic Chemistry Lab (C241,2) 2. Grade 12 (RESA) lab 3. Research overflow, Dr. Murray
HH123	1025		2 hoods 8 feet	X X	 X X X	 X	1 1 1 na	1. Quant. Anal. (C200) 1-2 expt. 2. Instrumental Analysis (C430) 3. Chemical Separations 4. Research, various faculty

Stockrooms

It is standard practice in our discipline to maintain a stockroom as a secure, central storage area for chemicals, glassware, and lab supplies. Our department maintains stockrooms on the 2nd and 3rd floors of Halenz Hall that are connected by a spiral staircase. Security is important, key card access is provided to student workers at appropriate times. Faculty and staff have 24x365 day access to the stockroom. There is a backup keycode access method available to faculty and staff. Both rooms have our standard departmental safety equipment: A fire extinguisher (maintained by AU Campus Safety), a first aid kit, a spill kit, eyewash fountain.

The Second Floor Stockroom (29x26=754 ft^2) serves teaching labs on the second floor and houses inorganic chemicals and a few organic solvents that are used in General Chemistry, the Intro to Chemistry sequence, and Consumer chemistry. The stockroom contains a 4 foot fume hood, a 2.5 ft x 2.75 ft storage cabinet for high concentration acids, and a 2.5 ft x 2.75 ft flammable storage cabinet. This stockroom has approximately 30 square feet devoted to Andrews ChemServices.

The Third floor stockroom (29x26=754 ft^2) serves teaching and research labs on the third floor and houses organic chemicals along with a few inorganic substances used in organic chemistry. Many organic solvents are flammable. To store these according to best practices, there are three 3.5 ft x 5.5 ft flammable storage cabinets. The university maintains an industrial (ethyl) alcohol license issued by the ATF. The alcohol is stored in a room under lock and key access to which only one member of the department has access to this room. This stockroom also houses apparatus used to prepare gallon quantities of distilled water. There is a 4 foot hood in this stockroom.

Glass blowing lab

The department maintains a glassblowing lab in HH228 (12x10=120 ft^2). Faculty and students have used this room to do scientific glassblowing and glassware repair. At approximately yearly intervals, Dr. G. William Mutch voluntarily repairs or constructs glassware. Dr. Ahlberg has also guided a student to work in the glassblowing lab. The glassblowing lab features a glassblowing lathe, an annealing oven, and a variety of appropriate equipment and supplies and is equipped with natural gas. While Dr. Mutch is available periodically, there is not currently expertise within the department to produce and repair complex scientific glassware. Drs. Ahlberg and Randall have rudimentary glass blowing skills.

Machine shop access

Andrews Physics Enterprises maintains a fabrication machine shop with a lathe, mill, drill press. Department faculty have used these on occasion for instrument fabrication.

Facilities requirements

Several of our instruments have specialized facilities requirements concerning airflow and electrical power. The special requirements of chemistry laboratories for either teaching or research are described in the next below.

- **Halenz Hall**: While we often take the buildings in which departments are housed for granted, the mechanical integrity of Halenz Hall as a building is an important consideration in housing departments that use instruments that require high-levels of mechanical precision. One benefit of the building itself, is that it enables us to obtain high-precision / high-accuracy masses of samples (to 0.1 mg). Anecdotes from an SDA school on our baseline list indicate that a newly constructed science building does not have the mechanical specifications to allow students to obtain measurements to this level of accuracy (while instruments can certainly read to this level, the reading is neither reproducible nor stable). Further the mechanical integrity of the building (low levels of environmentally induced vibration), benefits our nuclear magnetic resonance spectrometer and an optical laser. While most chemistry-specific facilitization can be retrofitted into pre-existing spaces (with considerable monetary expense and time), the mechanical features of the building need to be designed in from the start. We are grateful to our insightful stewards of the department and university for the wisdom to provide high levels of mechanical integrity in our building.
- **Natural Gas**: Natural gas is piped through all three floors Halenz Hall so that Bunsen burners can provide localized heat sources, most often in the second floor chemistry labs. Given the flammability of most organic solvents, flames are only rarely used in the organic chemistry areas of the 3rd floor of Halenz Hall. Natural gas is used in labs as supplied from this system.
- **House Air**: House air is provided from an air compressor in the facilities attic on the roof of Halenz Hall.
- **CDA Gas**: Clean, dry air (CDA) is provided by cleaning house air (input pressure 80+) with a Parker-Balston 75-62 purge gas generator. Cleaned air is provided at a flow rate of 80 SCFM (50+20+10 split to three sources) and an output pressure of 50+ PSI. This CDA air is supplied to a Fourier Transform Infrared (FTIR) spectrometer in the BCFL and to another on the third floor of Halenz Hall. The major consumer of CDA is the NMR. CDA is important for the NMR because it keeps the internal workings of this instrument clean from dust, oil, and water vapor that could corrode components of this complex instrument. CDA is also used to provide a gas purge for the FTIR instruments because both water vapor and carbon dioxide (CO_2) strongly absorb infrared radiation (the bases for the greenhouse effect). Peaks from these two gases can interfere with the

spectra obtained from the instrument. Further, some of the optical components in the FTIR instruments use salts like potassium bromide (KBr) which dissolve and degrade in the presence of water vapor, as does ordinary table salt. Flow rates provided for purging the FTIR spectrometers, particularly the one on the 3rd floor of Halenz, are lower than they should be (10 SCFM is provided; spec is 10 SCFH at 80 psi). The NMR (nuclear magnetic resonance spectrometer) in HH116 is a major consumer of CDA and the instruments reliability suffers a bit because we operate at the lowest end, and sometimes just below the instrument's flow @ pressure specification of 50 psi @ 50 SCFM. An additional air purification unit is recommended.

- **Electricity**: Several instruments have specialized power requirements other than US standard 120 VAC @ 60 Hz.
- **NMR**: The nuclear magnetic resonance (NMR) spectrometer housed in HH116 requires a high power (208V - 3 phase) uninterruptible power supply (UPS). The Andrews Plant Service department has partnered with us to provide the necessary facilities. However, sensitive electronics, such as the NMR, require that the power be stable. Our experience has been that during summer thunderstorms the NMR gets into an unusable configuration that renders the instrument unusable, until our local "instrument administrator" -- Dr. Randall, is able to recover the instrument. Most times, a simple instrument reset restores the instrument to functionality. However, in the last seven years these power supply problems have caused two high-impact failures: a critical circuit board failed and lead to a multi-month downtime; in a separate incident, the frequency synthesizer failed and had to be replaced. We hope that electrical main repairs undertaken by Plant Service in the summer of 2015 will alleviate these issues. Since that time the NMR has not suffered any of the issues. Since the issues occurred at low frequency anyway, it will take 1-2 years more before we can claim that the issue has been fixed.
- **GC-MS, ICP-OES, Ovens, etc**: The gas chromatography - mass spectrometer (GC-MS) and inductively coupled plasma-optical emission spectrometer (ICP-OES) instruments housed in HH123 have non-standard power requirements. Additional ovens in the department are wired to use either 220-VAC 1phase or 208-VAC 3 phase electricity.
- **Cooling Air**: The circuit boards in the NMR console generate a significant amount of heat. Therefore, a dedicated air conditioner is present in HH116.

Teaching labs and facilitized space

Third floor:

HH324,325. These are the organic chemistry labs. Each lab has six lab benches, each with one sink. Each lab bench can host up to four students. The bench tops are constructed of chemically and thermally stable material. Each lab bench has lockers for 16 students. In addition to organic chemistry lab, HH325 is used for RESA grade 12 chemistry and as overflow for Dr. Murray's research students. HH324 serves as overflow for both of these activities. Some of our smaller lecture courses (e.g., CHEM200 and CHEM431) are taught in HH324. As these are working labs, students are forbidden to eat or drink in these rooms. Both HH324 and HH325 have 10 fume hoods each. Practically speaking, the number of fume hoods limits the number of laboratory students that can simultaneously use this room. Additionally, variable flow-rate HVAC upgrades were installed in the HVAC upgrade project. Each lab room has 57 linear feet from 10 fume hoods. This room has our standard departmental safety equipment: A fire extinguisher (maintained by Andrews Campus Safety), a first aid kit, a spill kit, eyewash fountain and safety shower.

HH318. This room is Dr. Murray's research laboratory. It is equipped with a fume hood and ventilated chemical storage cabinets. There are 4 lab benches constructed of thermally and chemically resistant material. This research space features a fume hood and associated HVAC equipment.

HH315,6. These two rooms are Dr. Ahlberg's research laboratory. For the 2015-16 school year, Dr. Randall had a research student using the room. In the combined rooms, there are four lab benches constructed of thermally and chemically resistant material. The lab features a fume hood and associated HVAC equipment.

HH319. This room houses our Fourier Transform Infrared (FTIR) spectrometer. This instrument characterizes samples prepared by students in organic chemistry lab. It is therefore important that the instrument be adjacent to these labs. This room is provided with CDA purge air (vide supra).

PH339. This room in Price Hall, gained in the restructuring with MLS, houses much of the equipment and chemicals used by Andrews ChemServices. It serves as a classroom laboratory and materials storage for BCHM430. It is also used by Dr. Hayes and Dr. Nowack for research purposes. This room contains a standard lab-size rotovap, two large refrigerated centrifuges, a prep-HPLC system, analytical balances, a fume hood, a refrigerator/freezer, an industrial-size 20 L Buchi R-153 roto-evaporator, and ultrafiltration equipment along with chemicals, glassware, and other miscellaneous supplies.

Second floor:

HH220, 221: The two main teaching labs on the second floor of Halenz Hall (HH220 and HH221) are equipped with a counter material that is chemically and thermally inert: it won't dissolve in the presence of very strong acids or bases; it won't melt when 800 degree C crucibles are placed on it. Further, there are locker drawers in which individual student glassware supplies are stored. In each room, there are five lab benches, each of which has six single-student workstations and four sinks and utility towers (with 110VAC, natural gas, house vacuum, and three DC electricity stations). Further, each workstation on each lab bench has six unique lockers so that six sections can be served. Additionally, in each lab room there is another larger sink plumbed with house deionized water. Each lab room has 29 linear feet in five fume hoods. This room has our standard departmental safety equipment: A fire extinguisher (maintained by Andrews Campus Safety), a first aid kit, a spill kit, eyewash fountain and safety shower.

HH215: We typically use HH215 for more intense lab courses: our quantitative analysis lab (CHEM200) in the fall semester and our biochemistry lab (BCHM430) in the spring semester. We also use this as an overflow room for general chemistry as needed. The countertop is chemically and thermally resistant. The configuration of HH215 is slightly different from HH220, and HH221. HH215 features four lab benches with eight workstations (though it gets crowded with over six occupied). Each lab bench contains four sinks and four utility towers. Each workstation per bench has lockers for only three sections. HH215 has cabinets and desks around the outside of the room. Students appreciate the benches as places where they can analyze data during lab. The cabinets provide space for faculty to store supplies relevant to experiments taking place in the room. Dr. Merga uses HH215 for research. This room has non-standard electrical requirements for ovens. This lab has 11 linear feet of fume hood. This room has our standard departmental safety equipment: A fire extinguisher (maintained by Andrews Campus Safety), a first aid kit, a spill kit, eyewash fountain and safety shower. A side room accessible from HH215 or the hall (HH214) houses high-precision balances used in our analytical chemistry course. These balances are placed upon specially constructed weighing tables and benefit from the mechanical stability of the building.

First floor

HH123: This lab space houses many of our instruments that have a smaller footprint than the NMR. These instruments are used by students -- both for research and for lab experiences in our analytical chemistry courses. Most of the instruments in our department's instrumentation suite have been obtained recently, in the past 10 years. Several of the recent acquisitions replace older instruments. This room houses the following research-grade instruments whose benefits and functions are more thoroughly described on our department's web page:

1. Agilent High-performance liquid chromatography system featuring refractive index and UV-Vis detectors. Obtained in 2011.
2. Varian Cary 5000 UV-Vis research-grade scanning spectrometer with spectral coverage from 185 nm - 3300 nm. Obtained in approximately 2000 on an NSF grant.
3. Varian Cary Eclipse spectrofluorimeter. Obtained in 2011.
4. Agilent gas chromatography-mass spectrometry (GC-MS) instrument. Obtained in 2012.
5. Perkin-Elmer Optima 8000 inductively coupled plasma optical emission. Obtained in 2013.
6. Raman systems RSI 2001 integrated desktop Raman spectrometer. Obtained approximately 2005.
7. Cypress Potentiostat for performing electrochemical measurements. Obtained approximately 2005.
8. A vacuum line with cryogenic trap.
9. Continuum Mini-lite Nd:YAG bench-top laser. Obtained in 1990s. This instrument is housed in a separate room, with a closeable door within HH123. An instrumentation cable pass-through allows experiments to be conducted such that students have reduced exposure to this Class IV laser.

This room has our standard departmental safety equipment: A fire extinguisher (maintained by Andrews Campus Safety), a first aid kit, a spill kit, eyewash fountain and safety shower.

HH116: Highly specialized facilitization is required for the NMR. This room includes plumbed CDA, high-current 208VAC 3-phase electricity, and special cooling unit. The fact that this instrument is on the first floor of a mechanically stable building is important to the reliability and functionality of the instrument. The instruments' performance benefits from its location on the first floor of Halenz Hall.

BCFL: The Berrien County Forensic Lab is not routinely used by students or faculty (except those enrolled in CHEM410, Forensic Chemistry). However, this facility does host a LECO Time-of-Flight gas chromatography-mass spectrometer, which can be made available for limited use by student or faculty researchers. In addition to use-specific components beyond the scope of this report, this room features a fume hood and special electricity requirements for the TOF-GC-MS.

Instrumentation budget considerations

When considering the budget for our department, it is important to remember that sophisticated instrumentation is expensive to maintain and has a finite lifetime. Many of the instruments listed above replaced older instruments that lasted considerably longer than their manufacturer's expected lifetimes. However, while an older instrument may continue to function, getting guidance on use and replacement parts becomes challenging when the instrument is in its "end of life" phase as defined by the vendor. We feel that we would not be good stewards of the university budget by replacing functioning instruments that have reaching their "end of life." Accordingly, some of our faculty have continued to use, with good outcomes, very old instruments. Those instruments will fail eventually without the parts necessary to repair them being available or the parts being so expensive that replacement makes economic sense. The faculty place on themselves the responsibility of being good steward and are successful in that responsibility.

Summary of facilitized space

In summary, the space allocated to the Department of Chemistry & Biochemistry in Halenz Hall is highly-facilitized with details of the air handling, electricity, lab furniture, water, and even the mechanical properties of the building as described in more detail above. The department needs the space we have (and more), but the space that is useful for chemistry departments must also be facilitized to a greater extent than most academic departments. This facilitized space is consistent with best practices in chemical education and necessary to deliver a quality learning experience for future scientists and professionals in the broad area of medicine.

Halenz Hall upgrade

In the summers from 2010 to 2014, Andrews University renovated much of the infrastructure of Halenz Hall. A driving force for the renovation was the need to upgrade the HVAC system of the building to handle higher airflow and to provide the energy efficiency of computer control. This has helped the chemistry labs generate fewer offensive odors and represents a cleaner, healthier environment for our students, staff, and faculty.

The third floor teaching labs. The upgrade to the two third floor labs (HH324, 325) consisted of installing new equipment from the ground up: new fume hoods, new student workstations, and new HVAC system. The department faculty had a hand in working with the architects and vendors to provide input into the design and requirements for the upgrade. When the building was designed in 1972, it was not best practice to perform all reactions involving volatile chemicals in fume hoods. Only the most “dangerous” were performed in hoods. In the subsequent decades, safety best practices have evolved so that it is now best practice to perform ALL reactions involving volatile solvents (chemicals) in fume hoods. Prior to the upgrade, the five 8-foot fume hoods that were in the organic chemistry labs had to serve the entire lab section. This meant that sections of 20 second-year chemistry students had to work in pairs and that space to work in the fume hoods was crowded. This resulted in a situation where one partner in a lab pair was discouraged from being at the front lines of performing the experiment -- not the ideal for developing hands-on understanding that the lab experience is supposed to build. The renovated labs feature ten fume hoods per lab and allow all students to perform experiments. We feel that this renovation has improved the educational experience and safety of our students.

Renovation of Stockrooms. As mentioned above, the department maintains stockrooms on the second and third floor. The stockrooms originally contained carpeting and wooden cabinets—dating from 1972. The carpeting was no longer best safety practice because spilled chemicals become lodged in the carpeting and impossible to remove. Caustic chemicals and sustained moisture caused some of the wooden shelving to deteriorate, leading to chemical storage conditions that were not best practice. It so happens that the air flow to the second and third floors goes through the stockroom. Therefore, the HVAC renovation required completely emptying the stockrooms. Our department (with the generous help of alumni donors) took this opportunity to update this important feature of our department and re-did these two stockrooms from the ground up, installing plastic and steel shelves for chemical storage, installing proper acids and flammables storage cabinets (several flammables cabinets were present), and removing the contaminated carpeting.

New fume hoods and exhaust system throughout Halenz Hall. The air handling system for the entire building needed to be replaced in order to better manage energy consumption. This was accomplished by installing stainless steel ductwork with flow-sensing Bernoulli valves. This renovation was substantial and involved knocking out walls throughout the building, drilling 20+ holes through concrete floors. The badly stained fume hoods from 1972 that were in the second and first floor labs were replaced (in addition to those mentioned previously on the third floor). The automatic controls for these fume hoods help the university manage energy by controlling the flow rate. This means that, in the winter, heated air is exhausted at full rate only when the fume hood sashes are fully open. The general, analytical, and research chemistry labs have benefitted from the improved safety in the presence of strongly-smelling compounds like ammonia afforded by higher exhaust rates.

Refreshing Halenz 107 (Chemistry Amphitheater) The HVAC work required that the chemistry amphitheater be gutted to the cement floor. Again, the department with the help of alumni donors took this opportunity to update the carpeting, seating, AV system, and white board in this high-utilization room.

Impact of Medical Laboratory Science Renovation

Following the multi-summer renovation of Halenz Hall, the Department of Medical Laboratory Sciences (MLS) received funding from the administration to reallocate Halenz Hall space and renovate the space to meet their particular requests for their own lab spaces. The reallocation of Halenz Hall space resulted in the Department of Chemistry & Biochemistry losing space in Halenz Hall and gaining space in Price Hall.

In the summer of 2013, the Department of Chemistry & Biochemistry lost an office space and a faculty-members chemical research lab space. The resulting space allocation created Department of Chemistry & Biochemistry spaces that were much more fractured and much more inconvenient to use. The renovation cost the department and its faculty a summer of research time and many lost hours packing and unpacking supplies and instrumentation. Some of the cost was misattributed to our budget as well.

Overall, the MLS renovation was a negative imposition on the Department of Chemistry & Biochemistry for that summer and for the foreseeable future.

6. Are library holdings adequate for the program, and to what extent are they available and utilized?

Books

Table 4 gives the main library of congress numbers associated with chemistry and partner disciplines (physics, molecular biology) as well as the number of holdings in the James White Library. The Library has continued to invest in chemistry literature, including several "Advances in …" serials.

Table 4: Summary of holdings for chemistry and allied disciplines for the James White Library

Lib. of Congress	Description	James White Holdings
Q	Science, General	1,048
QC	Physics	3,545
QD	Chemistry	1,924
QD1-65	General, including alchemy	434
QD71-142	Analytical chemistry	241
QD146-197	Inorganic chemistry	105
QD241-441	Organic chemistry	431
QD415-436	Biochemistry	41
QD450-801	Physical and theoretical chemistry	555
QD901-999	Crystallography	124
QE	Geology	1,621
QH	Natural Hist and Biology	3,340
QM	Human Anatomy, histology, embryology	270
QP	Physiology (incl biochemistry)	2,355
QR	Microbiology	726

It is impossible for any university, including Andrews, to have every single book and monograph that might be valuable to research and departmental course work for. Through interlibrary loan, the MeLCat system, and physical proximity to international research universities, it is possible to get timely access to a respectable collection of scholarly books in our discipline. This can serve research and course development needs, but not actual library assignments.

MeLCat

The James White Library at Andrews University is a member of the Michigan e Library Catalog (MeLCat). This service gives faculty access to the book holdings of libraries at 50 colleges and universities in our state: including several leading research universities like Michigan State University, Wayne State University, University of Michigan-Dearborn (University of Michigan Ann Arbor is not part of this system).

Proximity to other research libraries

Andrews University is approximate 30 minutes from the University of Notre Dame du Lac, who maintain a fairly extensive discipline-specific library appropriate for their PhD program in chemistry. Five internationally known research universities and their libraries are located in driving distance: Michigan State University (2.5

hrs); University of Michigan Ann Arbor (3 hrs); University of Chicago (2 hrs); Northwestern University (2.5 hrs); Purdue University (2.5 hrs).

Endnote

The library provides a site license for the bibliographic management software EndNote. This program is useful for performing literature searches, often using either Web of Science or the EBSCO databases. However, this software is especially for managing the tedium of reference citations when writing papers. Dr. Randall reports that he has used this software when writing all of his papers. Dr. Hayes has also found the software very useful. Both teachers and students in CHEM430 use Endnote extensively, as do those in our chemistry seminar course.

Are there professional accreditation standards for library support?

Journals

The American Chemical Society Committee on Professional Training provides a recommended journal list. In order to maintain approval for our ACS degrees, we must report to the ACS CPT status with regard to these journals. The list is arranged into three tiers. **Tier I journals** are broad content scientific journals and include journals that publish high-impact primary research in broad areas of the natural and social sciences (Science, Nature, PNAS); leading journals that publish primary research in multiple areas of chemistry (Journal of the American Chemical Society, Angewante Chemie – Intl Ed), as well as leading review journals (*Chem. Rev.*, *Acc. Chem. Res.*). **Tier II journals** are leading journals in specific sub-disciplines of chemistry / biochemistry. **Tier III** journals include review journals from sub-disciplines, leading sub-discipline primary literature published by the Royal Society of Chemistry (the UK's chemistry society), and high-impact specialized literature. Obviously, there are far more chemistry journals than the 88 listed by the ACS CPT, but this represents a reasonable list to use to measure our on-campus library resources.

Table 6 lists the availability and publisher for all journals of the ACS CPT recommended list. **Table 5** summarizes the results. Of the ACS's CPT **Tier I** journals, Andrews has on-campus access to eight of these 10 journals (80%). In the past 7 years, we have acquired on-campus access *Angew. Chem. Intl. Ed.*; *Chem. Eur. J.*; *Nature*; and *Science*. This represents a substantial improvement in these high impact journals. While overall electronic, on-campus availability of all journals on the list is 54%, availability is 80% and 37% of the **Tier II** and **Tier III** journals, respectively. RSC and Elsevier publish many of the not-available journals in the **Tier III** category. Elsevier has a business model of publishing many journals and charging very high subscription rates. The missing access to RSC journals may be something to consider for the future. In summary, given the reality of the limited library journal budget at Andrews University, the available resources appear to be focused on appropriate high-impact journals.

Table 5: Summary of availability of Chemistry & Biochemistry journals on the ACS CPT "Recommended Journals List." Availability is on-campus through James White Library

ACS CPT "Recommended Journal List" Tier	Number available on campus
Tier I: General Content	8/10 = 80%
Tier II: Topical Highly Recommended	20/25 = 80%
Tier III: Topical Also recommended	20/54 = 37%
Total (Tier I – III)	48/89 = 54%

Table 6: Availability of all journals on ACS CPT "Recommended Journals List" for on-campus access.

Tier I. General Content	Status	Publisher
Accounts of Chemical Research	available	ACS
Angewandte Chemie International Edition	available	Wiley
Chemical Communications	no	RSC
Chemical Reviews	available	ACS
Chemical Society Reviews	no	RSC
Chemistry-A European Journal	available	Wiley
Journal of the American Chemical Society	available	ACS
Nature	available	Nature
Proceedings of the National Academy of Science of the USA	available	NAS
Science	available	AAAS

Tier II. Topical – Highly Recommended	Status	Publisher
Analytical Biochemistry	no	Elsevier
Analytical Chemistry	available	ACS
Biochemistry	available	ACS
Chemical & Engineering News	available	ACS
Chemical Biology (ACS)	available	ACS
Chemistry of Materials	available	ACS
Electroanalysis	available	Wiley
Environmental Science and Technology	available	ACS
Inorganic Chemistry	available	ACS
Journal of Biological Chemistry	available	ASBMB
Journal of Biological Inorganic Chemistry	available	SBIC
Journal of Chemical Education	available	ACS
The Journal of Chemical Physics	no	AIP
Journal of Chromatography A	no	Elsevier
The Journal of Organic Chemistry	available	ACS
Journal of Physical Chemistry A	available	ACS
Journal of Physical Chemistry B	available	ACS
Journal of Physical Chemistry C	available	ACS
Langmuir	available	ACS
Macromolecules	available	ACS
Nano Letters	available	ACS
Organic and Biomolecular Chemistry	no	RSC

Organic Letters	available	ACS
Organometallics	available	ACS
Trends in Biochemical Sciences	no	Elsevier

Tier III. Topical – Also Recommended	Status	Publisher
Advanced Functional Materials	available	Wiley
Advanced Materials	available	Wiley
Advanced Synthesis and Catalysis	available	Wiley
Advances in Heterocyclic Chemistry	no	Elsevier
Advances in Protein Chemistry	no	Elsevier
Analyst	no	RSC
Analytical and Bioanalytical Chemistry	available	Springer
Applied Catalysis A: General	no	Elsevier
Applied Spectroscopy	no	OSA
Biochemical Journal	no	Portland Press
Bioconjugate Chemistry	available	ACS
Biomacromolecules	available	ACS
Bioorganic Chemistry	no	Elsevier
Catalysis Reviews: Science and Engineering	no	Taylor & Francis
The Chemical Educator	no	independent
Chemical Physics Letters	no	Elsevier
Chemistry Education: Research and Practice	no	RSC
Chemistry Letters	no	Chem Soc Japan
Combinatorial Chemistry and High Throughput Screening	no	Bentam Science
Coordination Chemistry Reviews	no	Elsevier
Critical Reviews in Biochemistry and Molecular Biology	no	Taylor & Francis
Current Opinion in Chemical Biology	no	Elsevier
Current Organic Chemistry	no	Bentam Science
Dalton Transactions	no	RSC
Electrophoresis	available	Wiley
European Journal of Inorganic Chemistry	available	Wiley
European Journal of Organic Chemistry	available	Wiley
FEBS Journal	available	Wiley
Green Chemistry	no	RSC

Journal of the American Society for Mass Spectrometry	available	Elsevier
Journal of Applied Polymer Science	available	Wiley
Journal of Catalysis	no	Elsevier
Journal of Chemical Ecology	available	Springer
Journal of Chemical Information and Modeling	available	ACS
Journal of Chemical Theory and Computation	available	ACS
Journal of Chromatography B	no	Elsevier
Journal of Combinatorial Chemistry	available	ACS
Journal of Medicinal Chemistry	available	ACS
Journal of Molecular Biology	no	Elsevier
Journal of Organometallic Chemistry	no	Elsevier
Journal of Polymer Science Part A: Polymer Chemistry	available	Wiley
Journal of Proteome Research	available	ACS
Macromolecular Chemistry and Physics	available	Wiley
Molecular Cell	no	Cell Press
Nature Chemical Biology	no	Nature
Nature Structural and Molecular Biology	no	Nature
New Journal of Chemistry	no	RSC
Physical Chemistry Chemical Physics	no	RSC
Polymer	no	Elsevier
Supramolecular Chemistry	no	Taylor & Francis
Synlett	no	Thieme
Synthesis	no	Thieme
Tetrahedron	no	Elsevier
Tetrahedron Letters	no	Elsevier

How do library resources compare at benchmark institutions?

Table 7 summarizes information gleaned from publically available sources about the library resources for colleges and universities in the baseline list used in this report. Information was found in either academic bulletins or library websites. LaSierra University Library published an exceedingly helpful Annual Report. Overview metrics of a library are not a perfect measure of the library's suitability to a program, but according to the metrics below our university's library compares favorably with benchmark institutions. To some extent the Andrews metrics represent the breadth of programs offered at Andrews, however we feel that the library adequately supports our specific and particular program.

Table 7: Baseline Library Resource information

	Chem Dept Budget Total	Paper Books	Total holdings	Online full-text journals	# databases	Electronic Links Avail.
Andrews University	$26,109 $1,192,594	552,039	739,230	492,977	189	
La Sierra University	$1700 $324,720	217,945	642,066	51,180	79	Link
Southern University	(?) $267,850					Link
Pacific University	(?) (?)	150,000	250,000	33,000		Link
Walla Walla University		190,000	180,000		98	
Oakwood University					>40	
Hope College	(?) 2,500,000	387,823		37,888	164	Link
Calvin College		505,866	1,760,753	31,496	???	
Ashland University			300,000		>100	Link
University of the Pacific			400,000	thousands	>100	
Capital University						
Saint John Fisher College		160,000		200,000 electronic resources	181	Link
Wheaton College			Nearly 1,000,000	6,607 (thousands)		
Widener University		241,000	409,000		>80	Link
Xavier University			350,000	80,000	350	Link

Does building library support for your program strengthen others or vice versa?

The library resources for Chemistry and Biochemistry overlap with other natural sciences as well as applied sciences such as chemical engineering, biotechnology, and medical lab sciences. While each discipline has a unique perspective and literature, building library resources in Chemistry and Biochemistry can reinforce Andrews University programs in Physics, Biology, Biotechnology, Chemical Engineering, and Medical Lab Sciences. Further, areas of chemistry are strongly mathematical. Accordingly, augmenting mathematics library resources would be useful to Chemistry and Biochemistry. Further chemistry, through its contributions to technology, plays and important role in history, e.g. development of gunpowder; and in art, e.g. development of paint colors and stained glass window tints.

How are library resources used in the curriculum?

Chemistry seminar sequence (CHEM311,312,411,412)

A main learning objective of this 2-credit four-semester sequence typically taken by our junior and senior students is chemical information literacy. Based on guest lectures from a James White Librarian as well as departmental faculty, students learn about different types of chemistry literature including the practical details of how to a to look up articles in the primary literature. Over the course sequence, students use information obtained from library resources to write a research paper as well as to give three oral presentations. Students in this course use to search in the chemical literature using the ACS database, PubMed, and SciFinder.

Other curricular use of library resources

<u>BCHM422: Biochemistry II.</u> The students are required to search and obtain articles of current interest and relevance to cancer biochemistry.

<u>CHEM400: Chemical Separations</u>. Students review recent papers in the primary literature to identify an analytical measurement technique (usually either chromatography and/or mass spectrometry). Students describe how the method works and how the authors use the method.

<u>CHEM405: Medicinal Chemistry.</u> Students in this course critically read research articles that explore the molecular basis of medicines. Here, students look up papers in the primary literature, write a fully-referenced 12-page research paper, and give an oral presentation. Students have reported considerable satisfaction with this process and have enjoyed learning how to read the literature.

<u>CHEM415: Inorganic Chemistry</u>. Students prepare a fully referenced research proposal using library resources.

<u>CHEM432: Physical Chemistry II.</u> Students in this course are required to do a critical review of two recent reports in the primary literature. Two times during the semester, students peruse several articles from the physical chemistry literature and select one in which they summarize the method used, the key findings, and the evidence presented that supports the findings. Further, in each literature report assignment students critique the paper with regards to how well the authors make and support their point. Students often select papers from *J. Phys. Chem. A, B,* or *C*, though other journals are allowed.

<u>CHEM440: Instrumental Analysis</u> (old version): A similar assignment to the one now used in CHEM400 had been used in this course. (CHEM440 no longer exists and has been split into CHEM400 and CHEM430).

Other information literacy information assignments

Students in mid-level lab-courses CHEM200 (Quantitative Analysis) and CHEM241, 242 (Organic Chem Lab) need to look up chemical safety information as they prepare for work in the lab. Most often, this is information publically available on the internet. As organic chemistry (CHEM231, 232) students study about spectroscopy

(IR, NMR, Mass Spec) to help identify organic compounds, databases of spectra are useful. Again, this is information publically available on the internet.

Our department's LibGuide is available at **http://libguides.andrews.edu/chem**.

7. How rigorous is the curriculum for the preparation of graduates with skills necessary for a global workplace, who are able to adapt to changing environments and technology within their field? How well does the program engage students in collecting, analyzing, and communicating information, and in mastering modes of inquiry or creative work?

While our curricula for both our chemistry and biochemistry are fairly standard compared to benchmark institutions (*vide infra*), these curricula are somewhat unique in the academy because of their lengthy prerequisite sequences: e.g., 1 year of General Chemistry, followed by 1 year of organic chemistry. The standardization of the chemistry and biochemistry curricula is due in a large part to the prescriptive chemistry curriculum established by the American Chemical Society (ACS) committee on professional training (CPT) that partitions chemistry into five areas: analytical, biochemistry, inorganic, organic, and physical. Emphasizing studies at the interface of chemistry and biology, both the chemistry and biology components of our biochemistry curriculum are fairly standard also (*vide infra*).

Our BS Chemistry curriculum exposes students to the breadth of modern chemistry by requiring course work in each of the five disciplines of chemistry, along with a rigorous set of cognates including a full year of calculus and calculus-based physics. In all areas except for biochemistry and inorganic chemistry, BS Chemistry students have substantial lab requirements. Relative to bench mark institutions, our BS Chemistry and Biochemistry majors require a higher number of hours of chemistry/biochemistry lab. The absence of required labs in these two areas is fairly common among benchmark institutions. As one might anticipate (and is common among benchmark institutions), our BS Biochemistry curriculum includes a lab in biochemistry. Students working toward the ACS concentration in either the BS Biochemistry or BS Chemistry, experience a curriculum that is more mathematically rigorous, including math cognates through differential equations or calculus III as well as additional upper division chemistry course- (and lab-) work. Additionally, for the ACS concentration Biochemistry degree, calculus-based physics is required rather than algebra/trigonometry-based physics. Recent graduates from our department report that they felt that our curriculum prepared them well for graduate studies in chemistry.

Curriculum Map and Overview

Figure 1 displays the curriculum map developed for our program showing program learning objectives and courses where that objective is met. Assessment is addressed in more detail in Question 8.

Legend
- **X** student opportunity for outcome;
- **A** in assessment plan in WEAVE.

	CORE Departmental Curriculum										Upper Division Electives†					
	CHEM131-2 Gen Chem + Lab	CHEM231-2 Org Chem + LAB	CHEM200 Quant	CHEM210 Fr/So Seminar	CHEM311-2; 411-2 Jr & Sr Seminar	CHEM400 Separations	CHEM430 Instr Analy	CHEM431,41 Phys Chem I + Lab	BCHM421 Biochem I		CHEM415 Inorganic	CHEM432,42 Phys Chem II + Lab	BCHM422 Biochem II	BCHM430 Biochem Lab	CHEMx95 Indep Research	CHEM470; CHEM405; CHEM474; CHEM475
●**Knowledge**: Students will demonstrate a comprehensive knowledge and understanding of the identification and transformation of matter.	X A	X A	X A		X	X	X	X A	X A		X	X	X			X
●**Research**: Students will be involved in the discovery of (bio)chemical knowledge.					X										X A	
●**Communication Skills**: Students will effectively communicate (bio)chemical information to a diversity of audiences using a variety of formats.		X A	X A	X	X A	X	X	X				X		X A		X
●**Lab Skills with Safety and Env't Stewardship**: competency in common lab activities and instrumentation; use safe laboratory & waste management practices; understand impact of chemical activities on env't.	X A	X A	X A			X	X	X A				X		X A		X

Figure 1: Curriculum map. † Formally, not all of these are "upper division electives," but they are not required for all BS Chemistry and Biochemistry students. ***BS Chemistry*** *requires CHEM415. Beyond that* ***BS Chemistry-ACS*** *requires CHEM432,442, and CHEM47x (or CHEM405).* ***BS Biochemistry*** *requires BCHM422 and BCHM430. And* ***BS Biochemistry-ACS*** *also requires CHEM415 and CHEM432.*

Our curriculum endeavors to ensure that students know, apply and develop knowledge in the different sub-disciplines of chemistry (including biochemistry). Specifically, we want our students to be involved in the generation of chemical knowledge – research (or co-op) participation is an assessed program goal and is a degree requirement for all except for our BS Biochemistry major. Further, we want our students to be able to communicate with a variety of audiences in a discipline-specific way. Finally, chemistry and biochemistry have very practical aspects to them.

Our curriculum emphasizes in-lab work and skills very heavily. An important part of chemistry and biochemistry is the ability to successfully perform experiments in a way that involves creating and manipulating complex apparatus while obtaining accurate, precise, and repeatable results. Thus, our students will be exposed to 11 semesters of courses (major and cognates) with a lab component. The ability to plan and perform complex, practical (manual) tasks, is a transferable skill outside of chemistry and biochemistry. The ability to conscientiously react to unexpected situations is something that medical professionals and others face routinely.

Baseline Population and Graduation Trends

Table 8 presents some data for the institutions considered in the baseline analysis of our program. The ACS provides data from before 2000 (the 99-00 school year) to 2009. A request to the ACS committee on professional training (CPT) yielded preliminary data through 2013.

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Table 8: Selected data for baseline institutions. See footnotes for further explanation of columns and data sources.

	2016 Tuition & Fees[1]	**2016 UG Enroll**[1]	**2016 Numb. Fac.** [2]	**2016 SRM** [2]	**'00-16** [4] **Grads /year**	**'00-16** [4] **Grads /fac'ty**	**2010-** [5] **Grads /year**	**2010-** [5] **Slope**[6]
SDA Colleges & Universities								
Andrews Univ	$27,000	1,805	5.5 [7]	no	5.00	0.91	7.1	+0.7
La Sierra Univ.	$30,471	2,119	6	??	??	0.00	??	??
Southern Adventist Univ.	$20,650	2,728	7	no	14 [4]	2.00	14	na
Pacific Union C.	$29,064	1,640	5	yes	13 [4]	2.60	13	na
Walla Walla Univ.	$26,382	1,689	4	no	10 [4]	2.50	10	na
Oakwood Adventist Univ.	$16,720	2,016	6	yes	14 [4]	2.33	14	na
ACS Appr Regional					avg grad			
Albion C (MI)	$39,128	1,268	8	yes	21.21	2.65	25.5	-1.0
Calvin C (MI)	$30,660	3,894	17	yes	19.47	0.91	30.0	+0.8
Hope C (MI)	$30,550	3,432	17	yes	39.21	1.15	45.5	+1.8
Wabash C (IN)	$39,980	926	8	yes	9.214	0.44	11.3	+1.3
Beloit C (WI)	$45,050	1,303	6	yes	13.00	2.17	16.6	+1.1
ACS Approved (AU list)					avg grad			
Capital Univ.(OH)	$32,830	2,742	11	yes	4.79	2.31	8.0	+3.4
Saint John Fisher C. (NY)	$30,690	2,857	12	yes	6.79	0.57	10.3	-1.3
Seton Hall Univ. (NJ)	$36,926	5,817	14	yes	10.21	0.73	12.5	+0.8
Univ. of the Pacific (CA)	$42,934	3,810	15	yes	17.07	1.14	28.3	-2.1
Wheaton C (IL)	$32,950	2,432	11	yes	12.57	1.14	18.3	+4.5
Widener Univ (PA.)	$41,224	3,437	11	yes	3.29	0.30	4.5	+2.2
Xavier Univ (OH)	$35,080	4,633	13	yes	11.87	0.95	13.4	-0.7
Ashland Univ (OH)	$20,242	3,768	8	yes	4.13	0.52	5.0	+1.4
Benedictine Univ (IL)	$26,950	3,818	25	yes	6.43	0.26	3.5	+0.4
Univ of San Francisco (CA)	$42,634	6,845	13	??	9.57	0.74	10.5	-0.2

1. Enrollment and tuition are for 2016 and from US News (http://colleges.usnews.rankingsandreviews.com, accessed June 2016).
2. Number of faculty and stock room manager in 2016 from either direct response to survey or review of departmental web page (in summer 2016).
3. n/a
4. All available data between 2000–2016. For SDA colleges, historical data is not available, single year data is available from a survey in 2016 only. For ACS colleges, data is available from 2000-2013. Some ACS colleges also provided 2016 graduation counts, which is included.
5. Number of graduates per year using all available data between 2000–2016. See previous footnote.

6. Slope gives a very rough idea of recent growth or decline in the departments. The slope is the linear regression fit of yearly graduate counts as a function of year. While the data is not linear and graduate counts are small, a positive slope suggests average growth, while a negative slope suggests contraction.
7. For Andrews 0.5 faculty is allocated to the Berrien RESA Math & Science center. For this analysis focused on BS graduate productivity, the service to high school is not considered.

Figure 2 shows overall undergraduate enrollment for the colleges and universities considered in our baseline comparison. The solid dot that represents Andrews is toward the smaller end of the enrollment spectrum. Correspondingly, we observe that the number of departmental majors at Andrews per year is towards the lower end of the spectrum.

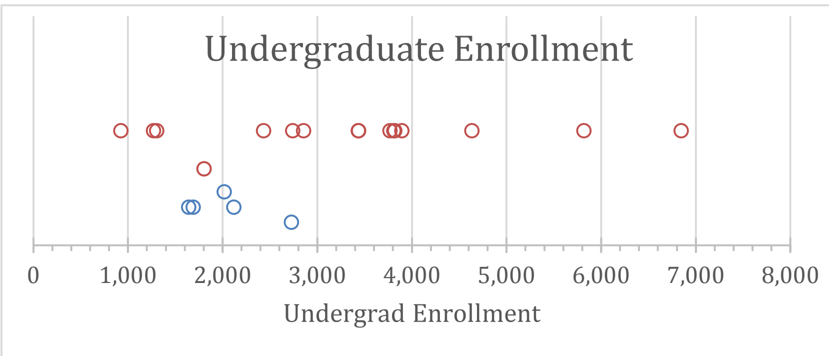

Figure 2: 2015 Undergraduate enrollment at baseline institutions (from US News). Solid orange circle is Andrews. Blue circles are SDA sister colleges. Orange circles are ACS accredited schools. The y-axis is used only to group institutions.

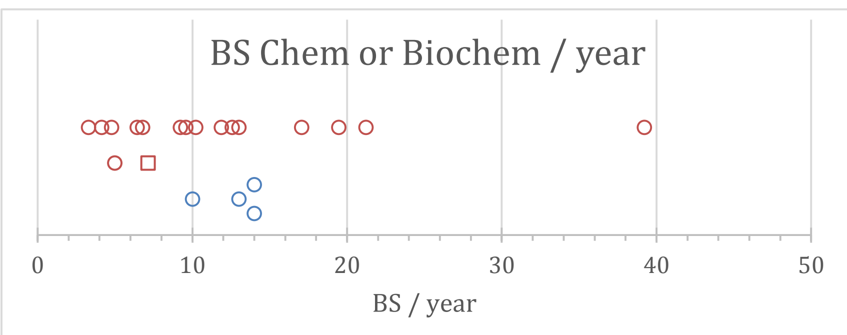

Figure 3: Annualized number of graduates in baseline line institutions. The solid orange circle represents Andrews (2000-2016); the solid orange square represents Andrews (2010-2016). Open orange circles represent a 14-year average from ACS approved department.

As a way to estimate department size within the university, **Figure 4** presents the ratio of number of Chemistry and Biochemistry graduates to the total undergraduate population. At most institutions, the number of majors in a department will be (significantly) larger than 4× the number of graduates due to students taking more than 4 years and/or more commonly switching out of the major. While there are some departments (in our baseline set) that produce a large number of chemists and biochemists, the Andrews Department of Chemistry & Biochemistry is towards the middle of the range, but below all of our sister SDA colleges (that provided data).

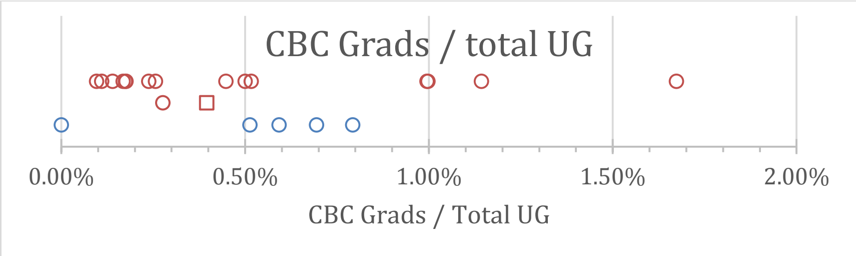

Figure 4: Chemistry and Biochemistry graduates for baseline schools divided by the total undergrad population (2015 from US-News). The solid orange circle represents Andrews (2000-2016); the solid orange square represents Andrews (2010-2016). Open orange circles represent ACS approved departments, based on 14 years (2000-2013) of data from ACS Committee on Professional Training (CPT); open blue circles represent SDA peers (data from 2016, personal communication). For schools with multiple years of data, the average number of graduates is divided by the 2015 enrollment (from US News).

All chemistry (and biochemistry) departments are "service" departments in that most students enrolled in their highest enrollment courses (Gen Chem, Org Chem, Biochem, Intro/GOB) are taken by students not in a departmental major. Thus, our department, and all chemistry and biochemistry departments, serve far more students than implied by departmental major graduates only. Therefore, the faculty in the department serve many students across the curriculum. Consequently, the ratio of departmental graduates to faculty (**Figure 5**) is an imperfect metric of departmental efficiency.

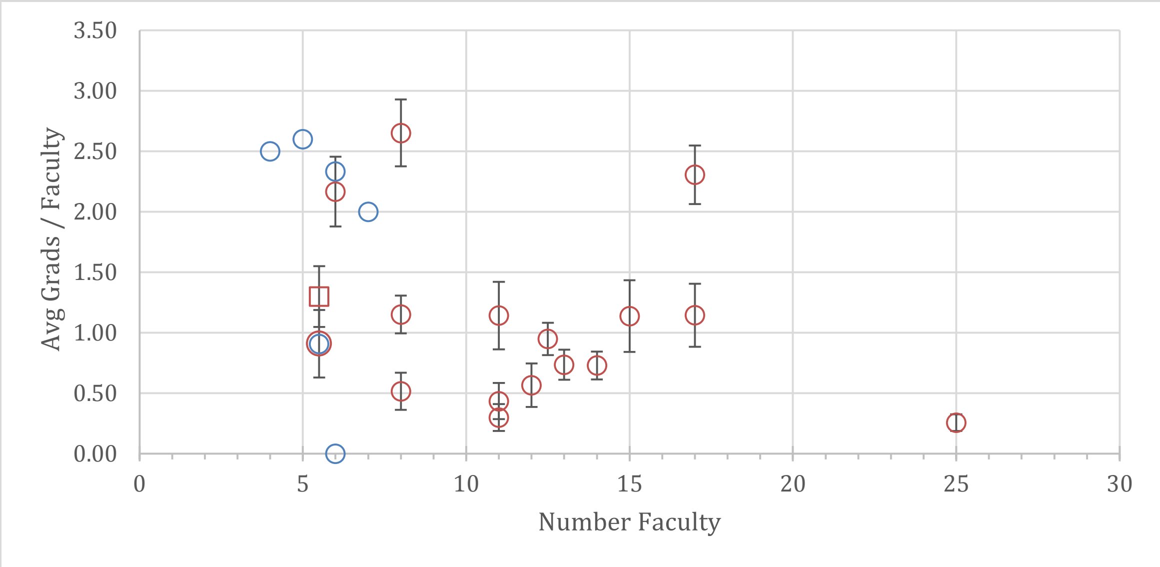

Figure 5: The ratio of departmental graduates / faculty for baseline schools as a function of number of faculty. The solid orange circle represents Andrews (2000-2016); the solid orange square represents Andrews (2010-2016), based on 14 years (2000-2013) of data from ACS Committee on Professional Training (CPT); open blue circles represent SDA peers (data from 2016, personal communication). Error bars are 90% confidence intervals: ($t_{90\%} \cdot s/\sqrt{n}$).

The ratio of graduates to faculty is shown for baseline schools in **Figure 5**. To account for the fact that students form relationships with their teachers as individuals (adjunct or full-time), we use the metric where adjunct faculty are counted at 100% (the trends are similar when adjuncts are counted differently, not shown). Our department does not use adjunct or visiting faculty, while other institutions make liberal use of such faculty.

Compared to ACS-approved institutions in **Figure 5,** the Andrews BS graduate to faculty ratio is in the middle of the range though we have a relatively smaller number of faculty. Importantly, this ratio for Andrews is similar to colleges with departments having two or three times the number of faculty. While there are ACS-approved colleges who have very admirable graduate to faculty ratios that are twice ours, the majority do not.

While Andrews as a whole, and our department in particular, is blessed with some very academically strong undergraduate students, most undergraduate students that matriculate at Andrews do not excel in mathematics and science reasoning. The mathematical rigor required to succeed in chemistry and biochemistry makes our departmental majors less appealing (or less efficient to complete) than might be the case for students matriculating at other colleges and universities (both ACS and non-ACS) where students might have a stronger math and science background.

Compared to SDA sister colleges, Andrews has a noticeably lower BS graduate to faculty ratio. In addition to different student populations that matriculate, as mentioned above, we attribute this to three factors.

1. As **Table 8** shows, all SDA institutions have a relatively small number of faculty. Southern has the largest department with seven chemistry faculty members, concomitant with its largest undergraduate enrollment. Since the denominator of the ratio (number of faculty) is relatively small, adding or subtracting one faculty changes the ratio in a way that appears substantive.
2. All of these institutions (except Oakwood) offer BA degrees in chemistry (and/or biochemistry) in addition to the more standard BS. While there are many good reasons to offer a BA in chemistry, which is an intentionally less rigorous major with respect to (bio)chemistry and cognates that intentionally allows students to focus on breadth across the academy. The breadth across the academy is valuable in the context of whole-person education that is a hallmark of SDA higher education. However, we feel that our program's rigor is one of the main reasons that students choose NOT to pursue a major in our department. A major with slightly reduced mathematical and scientific rigor, such as is found with a BA, might increase the major graduates by a student or two per year.
3. Finally, we do feel that our number of departmental majors at Andrews IS lower than some of our sister SDA schools. We attribute this to different campus cultures at each schools. Informal conversations with chemistry and biochemistry faculty at some of these departments (Southern, PUC, La Sierra) reveal that the number of biology majors and (bio)chemistry majors is about equal—or up to 2 biology majors to 1 (bio)chemistry major. At Andrews the ratio is, and has been in memorable history, about 4 to 1.

Further considering the data in **Figure 5** there may be a temptation to attribute to the lower BS graduate to faculty ratio to ACS approval because the ACS approval guidelines limit the number of contact hours per faculty to 30/year. By the ACS's definition, a contact hour is a university-scheduled hour per semester where students and teachers interact – e.g., lecture and lab count towards contact hours, but office hours or tutoring sessions do not. While any semester is a snapshot in time that reflects all the unique events in the university, **Table 9** clarifies that the contact hours invested by the Andrews chemistry and biochemistry faculty is similar to those of our sister STEM departments at Andrews, e.g., we are all fully loaded. Thus, it would seem that our number of graduates (and majors) are limited due to other more subtle factors, possibly including reduced mathematical and science reasoning capability. Again, this table is a snapshot in time and may reflect situations that occur in the natural progression of departments (new faculty, sabbaticals, etc.). The only message implied by this table is that the ACS-approved Department of Chemistry & Biochemistry does not have fewer contact hours than our sister STEM departments. Thus, the ACS limit on contact hours does not "protect" faculty in our department from working as hard as our colleagues in other STEM departments. By extension, we do not feel it is appropriate to interpret **Figure 5** to indicate that ACS approval implies a “less efficient” department in any way whatsoever.

*Table 9: Fall 2016 contact hours for Andrews STEM departments. (From online course schedule as of 07 Aug 2016). ** Biology maintains a Masters program, so more faculty effort is allocated to research. * Programs marked with a * participate in the RESA Berrien County Science Center. If courses are listed in the course schedule, contact hours from these courses are included.*

Fall 2016	Contact hrs	Faculty	Contact hrs/faculty
Biology**	87.75	9*	5.8
Chemistry & Biochemistry	67.9	6*	11.3
Engineering	86.5	5	11.5
Mathematics	47.0	6.5*	8.6
Physics	49.25	5*	6.6

Finally, it is valuable to evaluate historical graduation counts of BS Chemistry and Biochemistry majors. **Figure 6** graphs departmental graduation counts for Andrews and a subset of colleges on our peer list. (SDA colleges are omitted because no historical data is available). The figure reveals that some colleges grew in major count since 2010 (Capital University, Widener University, Wabash C, Ashland University), while other colleges stayed more or less constant (University San Francisco), and others shrunk (St. John Fisher University, Benedictine University). Data from schools that were omitted from the chart to enhance readability, show similar trends. It does not seem that there is a strong national trend in graduation counts. The chart reveals that since 2007 the general trend for our department has been one of growth. Though our number of majors per year is small and subject to substantial noise, since 2012, we have had our three largest graduating classes in the seventeen-year period shown on the chart.

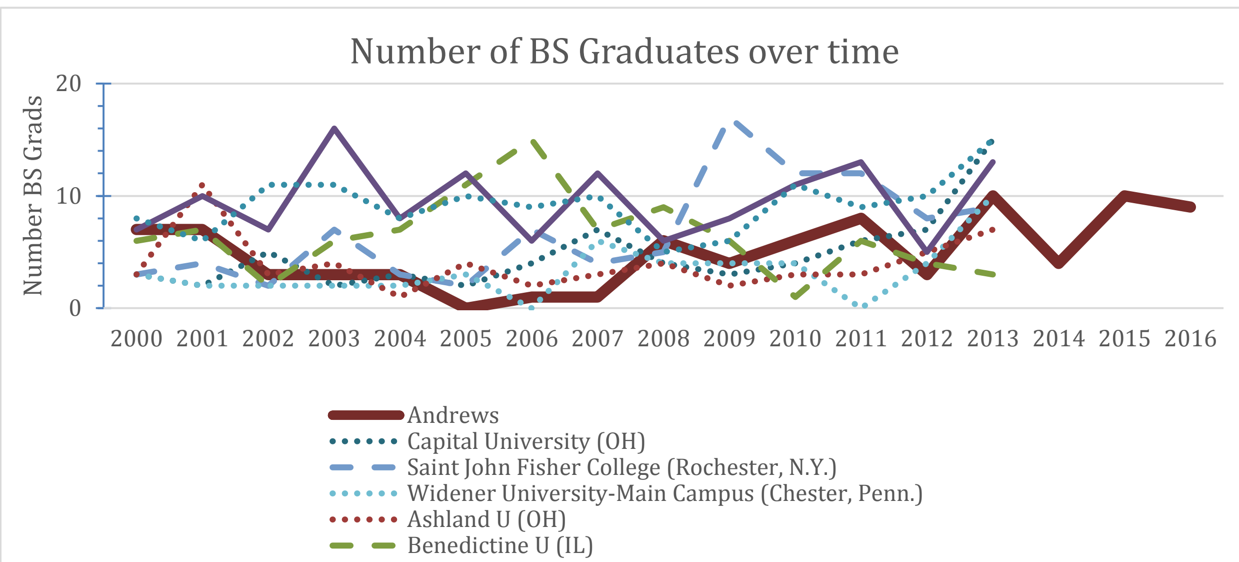

Figure 6: Number of BS graduates from selected baseline schools.

General Chemistry

While we don't feel compelled to explain each of our courses, our implementation of General Chemistry (CHEM131,CHEM132) is unique in some details. As the first course in our majors, the ACS refers to General Chemistry as a "foundational course." Because this class is an important part of many students' paths through Andrews, we feel that our General Chemistry curriculum and implementation bears some comment.

The full-year General Chemistry sequence provides a foundation across the sub-disciplines of chemistry with particular emphasis on Inorganic Chemistry and Physical Chemistry. While almost all colleges and universities offer a General Chemistry course, General Chemistry at Andrews University is somewhat unique in both its course structure and outcomes. The General Chemistry course taught by current teachers (Dr. R.T. Hayes and Dr. D.W. Randall) continues the practices of Dr. G. W. Mutch and R. A. Wilkins. General Chemistry CHEM131,132 is offered as a 4 credit class, with embedded lab. General chemistry meets for five 50 minute class periods per week plus a 170 minute lab.

While General Chemistry is typically taken by students in their first or second year of college, it is not a typical 100-level course when skills in Bloom's taxonomy are considered. Students who only master reproduction of knowledge fare poorly in General Chemistry. To excel in General Chemistry students must consistently master high-level learning skills where they develop solutions to problems and predict outcomes based on applying sometimes conflicting ideas and models. The content of the course is rigorous: we have historically covered and assessed students on 95% of the material in the book (1 chapter is omitted). This broad foundation in General Chemistry reflects the breadth and depth of our entire curriculum.

Students in General Chemistry

General chemistry is required for all natural science and engineering majors as well as pre-med, pre-dent, pre-pharm, and pre-PT students. **Figure 7** reflects the distribution of students in General Chemistry. Less than 10% of all students in General Chemistry are departmental majors. Fall 2014 was the first year that pre-PT students were required to take General Chemistry, otherwise the student distribution is representative of other years and semesters. Medical, Dental, and Pharmacy schools value knowledge diversity in their student bodies. As such, Andrews does not offer pre-med or pre-dent or pre-pharm majors. While the total engineering major count is growing at Andrews, some engineering majors require a single semester of chemistry, so the number of engineering students often drops in the second semester.

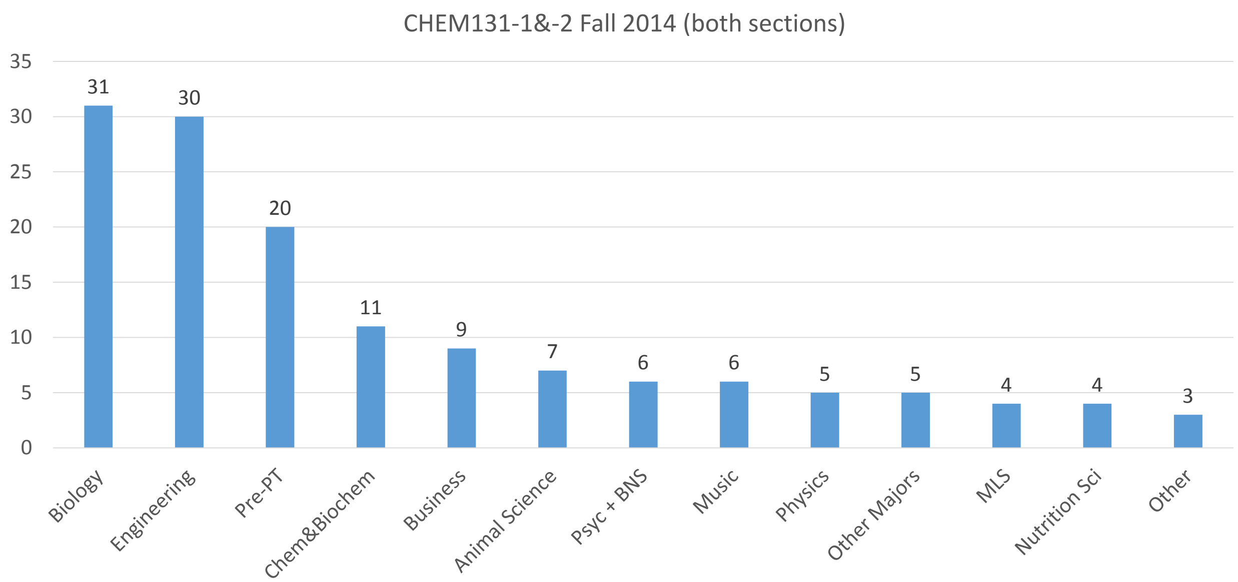

Figure 7: Distribution of majors in General Chemistry (in Fall 2014). Student with two majors were assigned to the major that required them to take General Chemistry. When both majors required General Chemistry, the first major was counted.

Five-day-a-week attendance in General Chemistry.

A unique aspect of our General Chemistry curriculum, is that students are required to attend 5 days per week. **Figure 8** illustrates that over 80% of students perceive value (help with learning General Chemistry; help earn a higher grade) in attending General Chemistry each day of the week. In other words, attending General Chemistry five days a week is not perceived by students as a "waste of time."

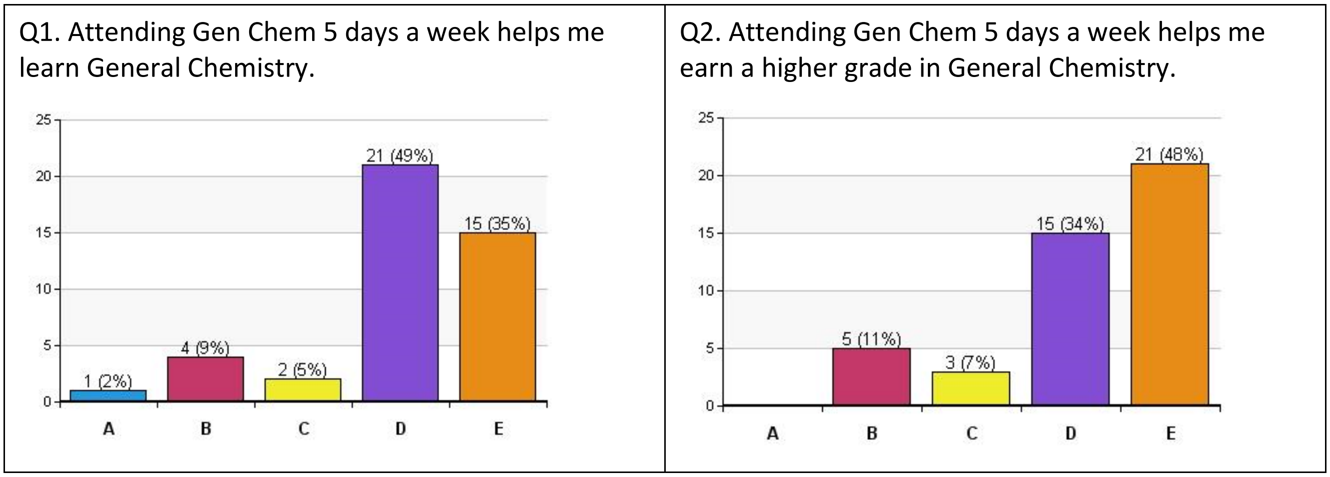

Figure 8: Student perceived value of 5-day a week attendance at General Chemistry. Responses were on a 5-point Likert scale with 5=E meaning strongly agree; 4=D meaning agree; 1=A meaning strongly disagree.

While students may perceive value, the question remains if they actually benefit from attendance 5 days per week. Historically (prior to 2014), it was required to attend General Chemistry 3 days per week, with the remaining two days being optional recitation. In contrast to recitations in some disciplines and in chemistry at other colleges, this was never a free-form discussion, but rather a guided problem-solving session lead by the course instructor. This is direct application of the knowledge presented on other days. **Table 10** presents historical data that compares total course percentages for students who attended optional recitation most of the time (>20× per semester) versus those who rarely attended (< 10× per semester). Semester after semester it is painfully clear that students who attended most recitation sessions did substantially better than those who attended a small fraction of recitations.

Table 10: Comparison of course percentages for students who attended optional recitation vs those who did not attend.

Course Percentages for students in Gen Chem				
	< 10 Recitations		> 20 Recitations	
	Attended	n	Attended	n
Fa2010	62.3	22	83.8	81
Sp2011	77.9	18	88.2	49
Fa2011	67.6	10	83.0	88
Sp2012	70.8	7	86.2	63
Fa2012	65.0	9	83.7	94
Sp2013	77.2	9	85.87	67
Fa2013	64.6	8	84.6	51
Sp2014	72.1	8	86.12	46
Avg %	69.7		85.2	
Grade	C		B+	

Regular attenders often earned about ***15% more points*** in the class: the high-attendance group average was B+, while the low-attendance group average was C. An ANOVA comparison of the low- and high-attendance groups suggests that the difference between outcomes for the groups is statistically significant ($p < 5\times10^{-6}$). Upon reviewing this data and because we accepted our responsibility to create an environment to maximize student outcomes, the faculty of the chemistry department elected to require attendance all 5 days a week starting in spring 2015. This is an example of using data to modify our program.

Meta-outcomes for General Chemistry

Two markers represent major above-average outcomes for students in the Andrews General Chemistry course:

1) How well do the Andrews students do compared to national averages?
2) What is the likelihood of the undesirable outcome of not passing the course?

Of course, General Chemistry has sophisticated course-level learning objectives, and merely passing a class is not an excellent outcome. However, these give some insights into the quality of student outcomes.

1) National norms on ACS standardized tests

For decades, the department has used a nationally normalized, cumulative, multiple-choice exam for as the final exam. We are pleased that many years around 10% of the class scores at or above the 95th percentile on the exam. This reflects the excellent students that are enrolled at Andrews. If we average the scores of all students on the exam and convert it to percentile (not the average of percentiles), the class average is in the 62-68 percentile range (program assessment is discussed later). While this is not outstanding, this result is substantially and consistently above the national norm score of 50th percentile. Considering that admission to the class (and Andrews) is relatively open, we feel that this reflects above normal student learning (as a whole). Thus, students appear to do a better under the Andrews method of teaching General Chemistry. While we have not made a specific correlation between ACS General Chemistry scores and scores on professional school exams, the MCAT, DAT, PCAT include sections with material from General Chemistry: MCAT includes a section called *Chemical and Physical Foundations of Biological Systems*; DAT includes a section called *General Chemistry*; PCAT includes a section called *Chemical Processes*.

2) Failure Rate (DFW rate)

One measure of student learning outcomes is the DFW rate—the percent of students who earn grades of D or F (or opt to withdraw) from the course. The DFW rate is computed by dividing the sum of the number of students who are assigned a grade of D or F or W by the total number of students who *started* the class (at the end of the "add period"). While we are unaware of a national database with DFW rates for General Chemistry, anecdotal evidence from internet discussion boards, departmental self-reviews and grant applications posted on the internet, and conversations with colleagues at conferences, suggests that DFW rates of 30% are typical for General Chemistry courses: Three students in ten fail a typical General Chemistry course! DFW rates of 20% are viewed as good. Since 2009, the DFW rate in General Chemistry taught with the Andrews method has averaged under 10%: ranging between 5 and 17%. The fact that the average student score is a percentile above 50th percentile, suggests that the lower-than-typical DFW rate for General Chemistry at Andrews is due to chemical knowledge, and not grade inflation.

Table 11: DFW rate data for General Chemistry at Andrews.

Semester	Sec	DFW n	DFW %
Fa2014	1+2	16	11.43%
Sp2014	1+2	10	10.00%
Fa2013	1	6	17.14%
Sp2013	1	15	11.28%
Fa2011	1	21	8.82%
Sp2012	1	20	8.77%
Fa2010	1	17	7.94%
Sp2011	1	22	10.00%
Fa2009	1	20	9.09%
Sp2010	1	11	5.19%

General Chemistry baseline results: 4 credits vs 5 credits

In a fall 2014 baseline study, we found that most colleges have four-credit General Chemistry courses (**Table 12**). An important consideration is that those courses require 3 or 4 student meetings (plus a lab) per week. Most colleges and universities in this study meet 3 days per week (plus a 3-hour lab). Recognizing the value of guided problem solving, many colleges and universities offer one discussion or workshop per week.

Table 12: Baseline General Chemistry results from 2014.

	Gen Chem Baseline (v1.1)			Total	Lecture		Laboratory		
	#	ACS	University	Cred	Credits	Meeting	cred	leng	Comment
	1	**ACS**	**Andrews University**	**4**	**4**	**MTWRF 1hr**	**0**	**3hr**	**TWO recitations per week**
1	**Regional Schools**								
	2	ACS	Hope College	4	4	MTWF 1hr	0	3hr	one discussion 1hr per week
	3	ACS	Calvin College	4	4	MTWF 1hr	0	3hr	Four lectures per week, no discussion
	4		Goshen College	4	4	MWF 1 hr	0	3hr	0 discussions per week
	5	ACS	Notre Dame	4	4	MWF 1 hr	0	3hr	one tutorial per week
	6	ACS	Grand Valley State	4	4	MWF 1hr	0	3hr	one tutorial per week
	7	ACS	IUSB	5	3	MW 1.5hr	2	3hr	one discussion 1hr per week; standard for IU
	8	ACS	Albion College	3.6	1.2CU	MWF 65 min	0	3hr	1course unit (CU) seems to be three credits
2	**SDA Schools**								
	9		PUC	5	5	MTWRF 1hr	0	3hr	5 all three qtrs; two discussions per week.
	10		LA Sierra	4	4	MTRF 1hr	0	3hr	All three qtrs
	11		Southern	4	4	MWF 1hr	0	3hr	one tutorial per week
	12		Walla Walla	4	3	MWF 1hr	1	3hr	0 discussions per week
	13		Union College	3	1CU	MWF 65 min	0	3hr	1course unit ≈ three credits; no discussion
	14		Southwestern	4	4	MWF 1hr	0	3hr?	No info on lab sched, lab fee implies lab, credit count implies lab; no scheduled discussion
	15		Oakwood	4	4	MWF 1hr	0	3hr	0 discussions per week
	16		Washington AU	4	4	MWF 1hr	0	3hr	0 discussions per week
	17		Kettering College	4	4	MW 1.5hr	0	3hr?	0 discussions per week
	18		Adv Univ Hlth Sci	4	3		1	3hr?	schedule unavailable
3	**Non-regional schools**								
	19	ACS	Stanford	5	5	MMWWF 1h	0	3hr	All three semesters; 2 discussions per week
	20	ACS	Westminster College (SLC)	4	4	MWF 1 hr	0	2hr	0 discussions per week
4	**AU Baseline list (non-SDA)**								
		ACS	Ashland University (Ashlan	4	4	MWF 1hr	0	3hr	no discussion
			Anderson University (Ande	4	4	MWF 1hr	0		no discussion scheduled
		ACS	Benedictine University (Lisl	4	4	MWF 1hr	0	3hr	no discussion
		ACS	Capital University (Columb	4	4	MWxF 1hr	0	3hr	1 workshop / week
			Carroll University (Waukesl	4	4	MWF 1hr	0	3hr	no discussion scheduled
			College of Mount St. Josepl	4	3	MWxF 1hr	1	2.5hr	1 recitation / week
		ACS	Saint John Fisher College (R	4	3	MWxF 1hr	1	3hr	1 discussion / week
		ACS	Seton Hall University (Soutl	4	3	MWxF 1hr	1	3hr	1 discussion / week
			Trinity International Univer	na					no chemistry program
		ACS	University of San Francisco	4	3	MWF 65min	1	4hr	no discussion
		ACS	University of the Pacific (St	5	5	MWF 75min	0	3hr	1 workshop / week
			Walsh University (North Ca	4	3	MWF 1hr	1	3hr	no discussion scheduled
		ACS	Widener University-Main C	4	3	MWxF 1hr	1	3hr	1 discussion / week

Three colleges and universities considered in the 2014 baseline results meet five days per week. Each of these offers General Chemistry for 5 credits/semester. Since the General Chemistry baseline study in 2014 was conducted, La Sierra has moved to 5 credits (note that the curriculum baseline study described elsewhere in this report includes some different schools).

To be clear: **how Andrews University offers General Chemistry has NO BASELINE PRECIDENT**. Andrews is the ***only*** college or university that requires attendance 5 days per week concomitant with the student benefits outlined above but allocates only 4 credits (per semester) for the course. Given that the effort expected and expended by students in General Chemistry and the teacher investment is equivalent to 6 credits by some accounting systems (5 days of class plus a 3-hour lab), it would be appropriate to increase the credit count of General Chemistry to 5 credits. We feel that 5 credits would balance effort expected by students and practicality of overall credit count for a diversity of majors. Federal guidelines require institutions to have uniformity in credit count calculations across the curricula: currently, General Chemistry is undervalued by the rubric used at Andrews University to assign number of credits.

Majors: curriculum graphic showing prerequisite sequences

Figure 9 through **Figure 12** highlight the pre-requisite sequences for our chemistry and biochemistry majors. A full year of General Chemistry should be taken in the first year of college, followed by a full year of Organic Chemistry in the second year of college. General Chemistry and Organic Chemistry are yearlong courses that must be taken in order. There is more flexibility in courses beyond the second year.

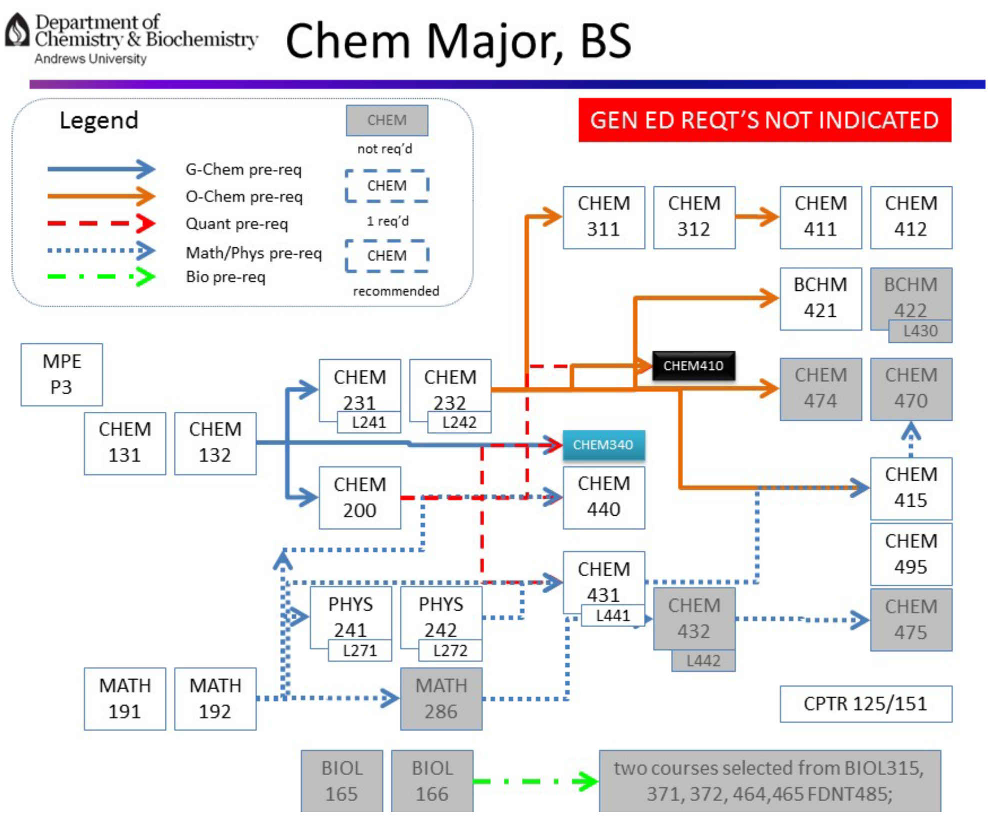

Figure 9: Courses for our BS Chemistry major showing pre-requisite connections.

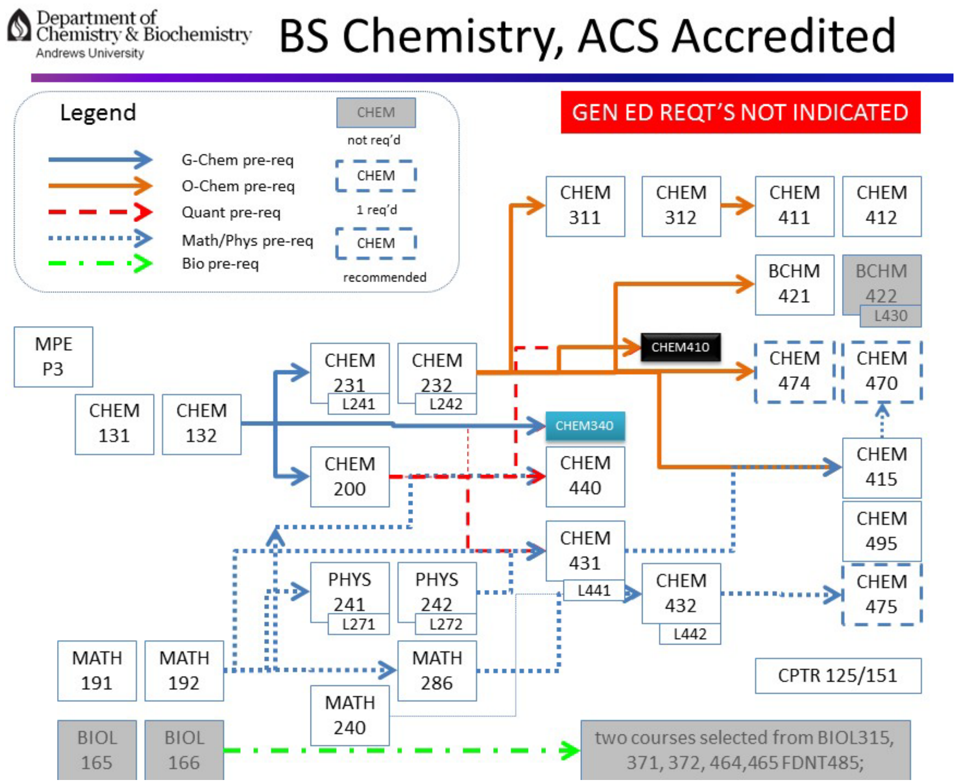

Figure 10: Courses for our BS Chemistry-ACS major showing pre-requisite connections.

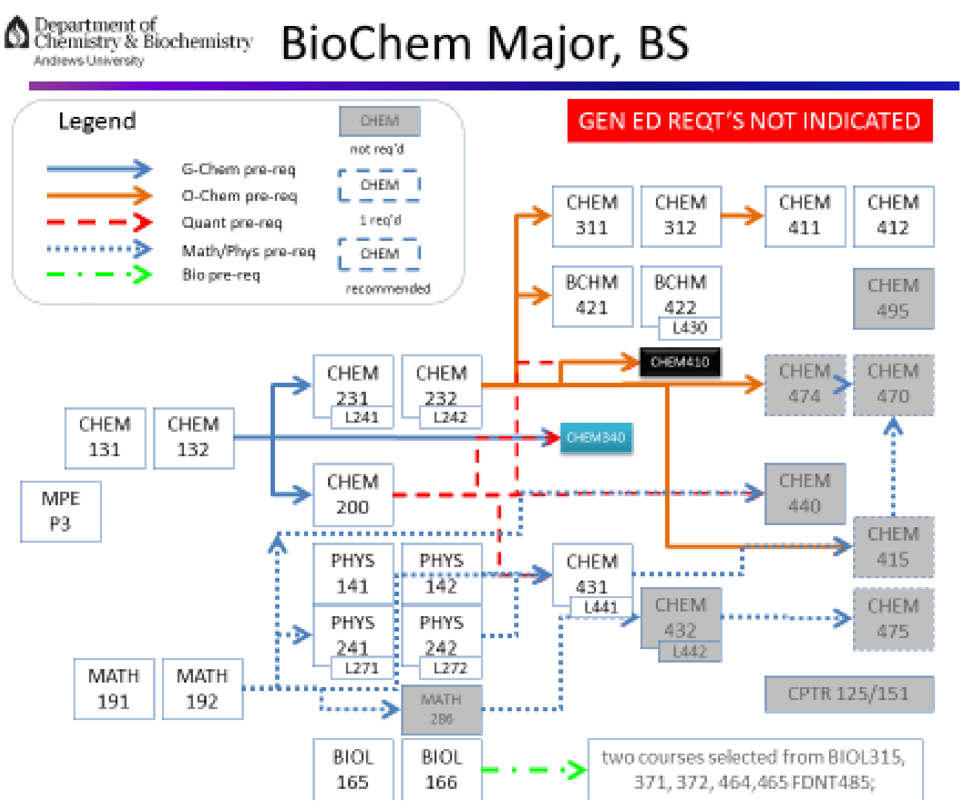

Figure 11: Courses for our BS Biochemistry major showing pre-requisite connections.

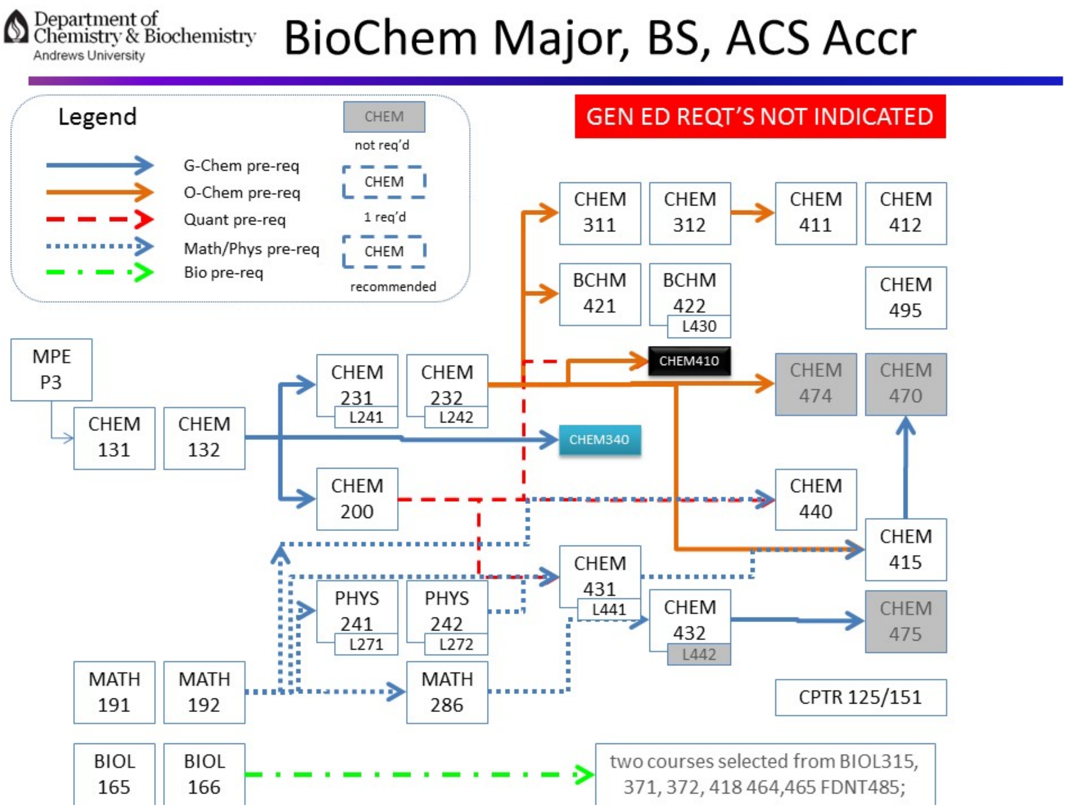

Figure 12: Courses for our BS Biochemistry-ACS major showing pre-requisite connections.

How does our curriculum compare with similar or competing programs? Our BS Biochemistry and BS Chemistry majors offer students parallel or better learning opportunities than other colleges and universities.

Baseline curriculum comparison (Chemistry)

Table 13 summarizes the curricula of BS Chemistry programs at baseline institutions. The colleges and universities selected represent an *ad hoc* mixture of schools from the official Andrews baseline list, schools whose chemistry programs are recognized by the ACS, and strong schools in the region.

Table 13: Curricula of BS Chemistry Majors (non-ACS).

College	Cred.	Lab hrs	Cr	hr	Cr	Lab hr	Cr	hr	Cr	hr	Cr	hr	Cr	hr	UD electiv		Biol.	Sems	Phys.	based?	Calc.+	Stats	CPTR
Andrews, BS Chemistry	56	510	8	90	8	120	4	0	8	240	4	60	4	0	2		0		10	YES	8	0	3
Andrews, BS Chemistry (ACS)	62	570	8	90	8	120	4	0	8	240	8	120	4	0	4		0		10	YES	8	0	3
PUC, BS Chemistry	58	300	10	90	8	90	0	0	5.3	80	6.7	40	2	0	7.3		0		8	NO	10.7	0	0
LaSierra, BS Chemistry	66.3	480	10	90	9.3	150	0	0	8	120	10	120	0	0	11		0		10	NO	8	0	0
Southern, BS Chemistry	64	420	8	90	8	90	4	0	8	120	7	60	4	60	3		0		10	YES	12	0	0
Walla Walla, BS Chemistry	64.67	360	8	90	9.3	90	0	0	4	0	10	180	0	0	12		0		8	NO	10.7	2.67	0
Oakwood, BS Chemistry	73	540	8	90	8	90	4	60	12	180	8	120	0	0	3		4	1	8	NO	18	0	0
Xavier University (OH) BS Chemistry	66	420	8	90	11	90	3	0	8	120	8	60	4	60	4		0		8	YES	12	0	0
Calvin College (MI) BS Chemistry	58	300	8	90	10	90	4	0	4	60	4	60	4	0	4		0		8	NO	12	0	0
St John Fisher BS Chemistry	77	420	8	90	13	90	3	0	10	120	10	120	3	0	7		0		8	YES	15	0	0
Seton Hall BS Chemistry	64	240	9	90	10	90	3	0	4	60	3	0	3	0	16		0		8	YES	8	0	0
Capitol U BS Chemistry	56	420	8	90	8	90	0	0	8	120	8	120	4	0	4		0		8	YES	8	0	3
Hope C BS Chemistry	52	345	8	90	9	120	0	0	4	45	8	90	3	0	4		0		8	YES	8	0	0
Pacific, Univ of BS Chemistry	74	345	10	90	10	120	4	0	8	90	12	45	4	0	0		0		10	YES	16	0	0
Benedictine BS Chemistry	65	405	8	90	8	90	0	0	8	90	8	90	4	45	7		0		10	YES	12	0	0
Wheaton BS Chemistry	52	360	4	45	8	90	0	0	4	90	8	45	6	90	6		0		8	NO	8	0	0
Ashland BS Chemistry	60	270	8	45	8	90	0	0	4	45	8	90	0	0	8		0		10	YES	14	0	0
Widener BS Chemistry	65	405	8	90	8	90	0	0	8	90	8	90	4	45	7		0		10	YES	12	0	0

Discussion of baseline findings (BS Chemistry)

- Credit count by sub-discipline: **Table 13** demonstrates that Andrews offers a chemistry curriculum that is particularly well-rounded in comparison to baseline institutions because Andrews requires student to take course work in all five sub-disciplines of chemistry including biochemistry. Closer inspection of this table reveals that the credit counts in the sub-disciplines of chemistry offered at Andrews are within range of the sub-discipline credit counts offered by baseline schools.
- Total Major plus Cognate Credit count: **Figure 13** shows that Andrews overall credit count for BS Chemistry major (major classes plus cognates) is towards the lower end of the range of credit counts in baselined colleges and universities. For chemistry, the average credit count is 62.9, ranging from 52 to 77 semester credits. This range in major plus cognate credit count is substantial (approx. 50%=(77-52)/52).

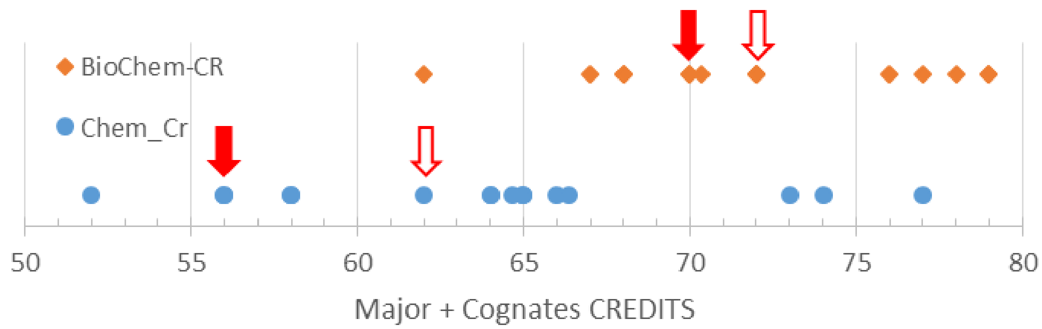

Figure 13: Major plus cognate credit counts for BS Chemistry and BS Biochemistry. Red Arrows are for Andrews regular (solid arrow) and ACS (hollow arrow) degrees. Credit counts for colleges on the quarter system have been calculated by converting to semester credits by multiplying quarter credits by 2/3.

- **Figure 14** reveals that Andrews has among the highest number of lab hours required for BS Chemistry. This count includes only lab hours required in the major, not cognate courses: The only cognate for chemistry majors with a lab is physics, which includes a 1-day a week lab. All baseline programs would have such a lab. Note that the quality of estimates for lab hours at other colleges is imperfect. Andrews seems to have a particularly high number of lab hours for analytical chemistry, where our sequence requires 4 labs.

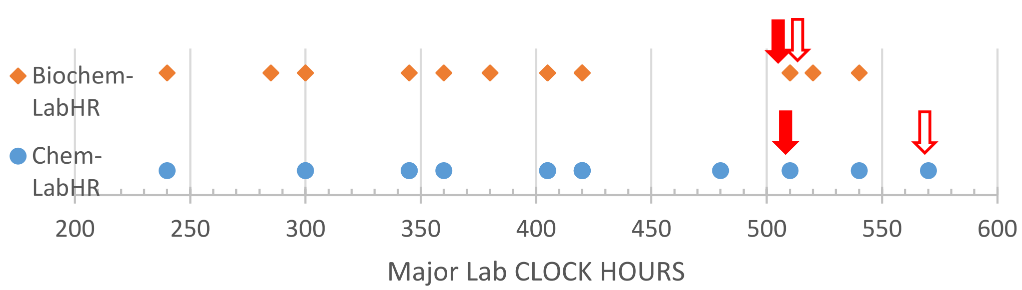

Figure 14: Total clock hours spent in lab for BS Chemistry and BS Biochemistry majors: a value of 400 means that to earn that major, a student should have spent 400 total hours in lab. Red Arrows are for Andrews' regular (solid arrow) and ACS (hollow arrow) degrees. Credit counts for colleges on the quarter system have been calculated by converting to semester credits by multiplying by 2/3.

- **Specific chemistry courses**
  - Full years of General Chemistry and Organic Chemistry (with labs) are universally required. La Sierra requires an extra semester of advanced organic chemistry.
  - Biochemistry: About 50% of baseline colleges (7 of 16) explicitly require biochemistry for non-ACS chemistry majors. For interested students, it is often possible to take biochemistry as an upper division chemistry electives (see upper division choices below). Only 1 of the 16 institutions requires a biochemistry lab for BS Chemistry students. At Andrews, our BS Chemistry students must take Biochemistry I, which does not include a lab.
  - Analytical Chemistry: Most (10 of 16) baseline institutions have the equivalent of two semesters of analytical chemistry for a total of 8 credits. Most often each course is structured as 3 lectures plus 1 lab per week. At Andrews, our analytical chemistry sequence is a bit more lab heavy and it is structured as follows:
    - 4Cr CHEM200 (Quantitative Analysis) — 2 lectures + 2 labs/week
    - 2Cr CHEM400 (Chem. Separations & Analysis) — 1 lecture + 1 lab/week
    - 2Cr CHEM430 (Instrumental Analysis) — 1 lecture + 1 lab/week
  - Inorganic: While most colleges (12 of 16) explicitly require a lecture course in inorganic chemistry, only 5 include an inorganic chemistry laboratory experience. At Andrews, we follow this trend. We do offer an optional advanced synthetic chemistry course (CHEM470).
  - Physical Chemistry: Most colleges (14 of 16) require a full year of physical chemistry. Often each semester includes a lab. However, some schools have a single semester of physical chemistry lab. At Andrews, only one semester of physical chemistry is required for BS Chemistry students. BS Chemistry-ACS students take a full year of physical chemistry, with a lab each semester.
  - Integrated lab: One or two baseline institutions have an advanced chemistry lab that integrates labs for upper-division courses in analytical, physical, and (sometimes) inorganic chemistry. At Andrews, each upper division course maintains its own lab. Our approach ensures that the lab experience amplifies and augments class work.
  - Several baseline institutions (9 of 16) structure their BS Chemistry majors with upper-division chemistry choices (often called electives). For instance, students must take two out of three listed in-depth courses – for example: choose two from Analytical Chemistry II, Physical Chemistry II, Advanced Inorganic Chemistry, etc. At Andrews, a chemistry major has no choices in the chemistry courses that they must take.
  - Research and Chemistry Seminar: Most baseline institutions have a few credits (2-4) devoted to a chemistry seminar, research, capstone experience, etc. At Andrews, we require 2 credits of chemistry seminar. Additionally, the following three majors require a research or co-op experience: BS Chemistry, BS Chemistry-ACS, BS Biochemistry-ACS. While there is likely considerable variation in the way research and/or chemistry seminar is managed and delivered across baseline institutions, the fact that it is a requirement is very common.
- **Cognates**
  - Mathematics: two semesters of calculus are the minimum requirement and 5 of 16 schools require only this level. Many schools (11 of 16) require 3 or more semesters of mathematics for their chemistry major, with the third semester most commonly being multivariable calculus or differential equations. At Andrews, 2 semesters of calculus are

required. The Andrews ACS chemistry major requires one more semester of mathematics, either differential equations or multivariable calculus.

- Physics: No institution requires more than a single year of physics. Most (10 of 16) chemistry majors surveyed require calculus-based physics. One of 6 SDA baseline institutions (in addition to Andrews) appears to require calculus-based physics for their BS chemistry major. While calculus-based physics is always allowed, 37% of baseline colleges allow algebra-based and trig-based (non-calculus-based) physics to meet the physics requirement.
- Computer: One college (in addition to Andrews) requires a computer-programming course. At Andrews, students are required to take a computer programing course.
- Biology: Only one of 16 baseline institutions requires one semester of general biology. This is to meet a life-science general education requirement. At Andrews, BS Chemistry students do not need to take biology.

Baseline curriculum comparison (Biochemistry)

Table 14 presents a baseline summary of the BS Biochemistry programs at the same baseline institutions.

Table 14: Curricula of BS Biochemistry Majors (non-ACS)

BS BIOChemistry Baseline Curriculum	Total	Total	Gen Chem		Org Chem		Biochem		Ana. Chem.		Phys Chem.		Inorg Chem		Other Chem	COGNATES						
College	Sem Cred.	Lab hrs	Cr	Lab hr	Cr	Lab hr	Cr	Lab hr	Cr	Lab hr	Cr	Lab hr	Cr	Lab hr	Res; Sem; UD ele	Biol.	# Sems	Phys.	Calc-based?	Calc.+	Stats	CPTR
Andrews, BS Biochemistry	70	510	8	90	8	120	8	0	8	240	4	60	0	0	2	16	4	8	NO	8	0	0
Andrews, BS BioChemistry (ACS)	72	510	8	90	8	120	4	0	8	240	7	60	4	0	2	13	3	10	YES	8	0	3
PUC, BS Chemistry-Biochemistry	72.0	380	10	90	8	90	9.33	80	2.7	80	6.7	40	2	0	6.0	11.3	3	8	NO	8	0	0
LaSierra, BS Biochemistry	70.3	520	10	90	9.3	150	8	120	5.33	80	4	80	0	0	8.33	10	2	10	NO	5.33	0	0
Southern, BS Chem (bioch emph)	68	360	8	90	8	90	8	60	4	60	4	60	0	0	6	15	3	8	NO	4	3	0
Walla Walla, BS Biochemistry	78	420	8	90	8.7	90	9.33	120	2	0	6.67	120	0	0	8.67	18.7	5	8	NO	5.33	2.67	0
Oakwood, BS BIOChem	76	540	8	90	8	90	8	120	12	180	4	60	0	0	4	16	4	8	NO	8	0	0
Xavier University (OH) BS Natural Science	67	240	8	90	8	90	0	0	1	60	3	0	0	0	12	20	5	8	NO	4	3	0
Calvin College (MI) BS BIOChemistry	62	285	8	90	10	90	9	60	4	45	0	0	4	0	3	8	2	8	NO	4	4	0
St John Fisher BS Chemistry-Biochem	79	420	8	90	10	90	7	0	10	120	10	120	3	0	3	12	3	8	YES	8	0	0
Seton Hall BS BIOChemistry	72	300	9	90	10	90	7	60	4	60	3	0	0	0	7	16	4	8	YES	8	0	0
Capitol U BS BIOChemistry	70	420	8	90	8	90	7	60	8	120	4	60	0	0	7	12	3	8	YES	8	0	3
HOPE C BS BIOChemistry/molec biol	68	345	8	90	9	120	7	45	4	45	4	45	0	0	8	12	4	8	YES	8	0	0
Pacific, Univ of BS BIOChemistry	77	300	10	90	10	120	11	45	4	45	4	0	0	0	4	16	4	10	NO	8	0	0
Benedictine BS BIOChemistry/Molecbiolo	79	405	8	90	8	90	10	180	4	45	4	0	0	0	4	19	6	10	YES	12	0	0
Wheaton BS Chemistry-Biochem conc	53	360	4	45	8	90	7	45	4	90	6	45	4	45	4	0	0	8	NO	8	0	0
Ashland BS Chemistry-Biochem conc	67	270	8	45	8	90	7	45	4	45	4	45	0	0	0	16	4	10	YES	10	0	0
Widener BS Chemistry-premed	75	405	8	90	10	90	8	90	4	45	8	90	0	0	6	12	3	8	YES	8	3	0

Discussion of findings (BS Biochemistry)

- Major name: Several names are used for the major that focusses on the interface of chemistry and biology. Among the baselined colleges and universities 8 of 16 offer a major named Biochemistry; others offer majors called Chemistry–Biochemistry Concentration, Chemistry–Biochemistry Emphasis, Biochemistry/Molecular Biology, or Natural Science. While the majority of biochemistry majors are offered by the chemistry departments at the baselined institutions, there are a few that are managed as interdisciplinary majors.
- Total major plus cognate count: Table 14 shows the Andrews biochemistry curriculum is in the middle of the range for the baseline institutions. When comparing the data for chemistry majors (◇ symbol) and biochemistry majors (● symbol) in Figure 13, the range in major plus cognate credit counts for biochemistry is substantially smaller than the range for chemistry majors: 27% compared to 50%.

- **Figure 14** shows that Andrews has among the highest number of lab hours (scheduled clock hours) required for a biochemistry major. This figure does not include lab hours required by cognate courses: both General Biology and General Physics include two semesters of 1-day a week lab and upper division biology courses typically have 1 lab per week. As in the case of chemistry majors, the estimates for lab hours are not precise.
- Specific adjustments for BS Biochemistry relative to BS Chemistry
    - Multiple semesters of biochemistry are required by all sixteen baseline institutions: most schools require two semesters of biochemistry lecture and one semester of biochemistry lab.
    - Inorganic Chemistry is usually not required. Only 4 of 16 require inorganic.
    - Analytical Chemistry requirements are commonly lighter (7 of 16)
    - While the above adjustments to areas of the chemistry curriculum judged to be less "biological" might be approximately credit neutral, the overall credit counts are higher for the biochemistry major than for the chemistry major due to the addition of cognates in biology: a year of general biology (Foundations of Biology at Andrews) and 1-2 upper division biology courses. See **Figure 15** for a comparison of biology semesters required.
- Science Cognates for Andrews' BS Biochemistry major match baselined programs.
    - Mathematics: Some biochemistry majors, particularly at sister SDA institutions, appear to have weaker calculus requirements: Five of 16 (including 3 of 6 SDA sister institutions) allow for 1 semester of calculus plus statistics rather than two full semesters of calculus. Only 1 of 16 institution requires more than two semesters of calculus for a BS Biochemistry-like major. At Andrews, 2 semesters of calculus are required.
    - Computer: One of 16 schools requires a course in computer programing. At Andrews, no computer programming class is required for biochemistry majors.
    - Physics: A little over half (9 of 16) of biochemistry majors surveyed allow for a year of non-calculus-based (aka algebra- and trigonometry-based) physics. The balance of BS Biochemistry majors (7 of 16) require calculus-based physics. At Andrews, taking 2 semesters of non-calculus-based physics meets the requirement for BS Biochemistry.
    - Biology: **Figure 15** reveals that the biochemistry major at most baseline institutions requires a total of 3-4 semesters of biology. This is most generally a full year of general biology (Foundations of Biology at Andrews) and 1-2 semesters of molecularly-focused biology courses such as genetics, cell and molecular biology, systems physiology, or a combined anatomy and physiology, etc. The exact number of biology credits ranges from 0 (at Wheaton?!) to 20. At Andrews, four semesters of biology are required for 16 credits. Some of our majors elect to pursue 4 more credits in biology to earn a minor.

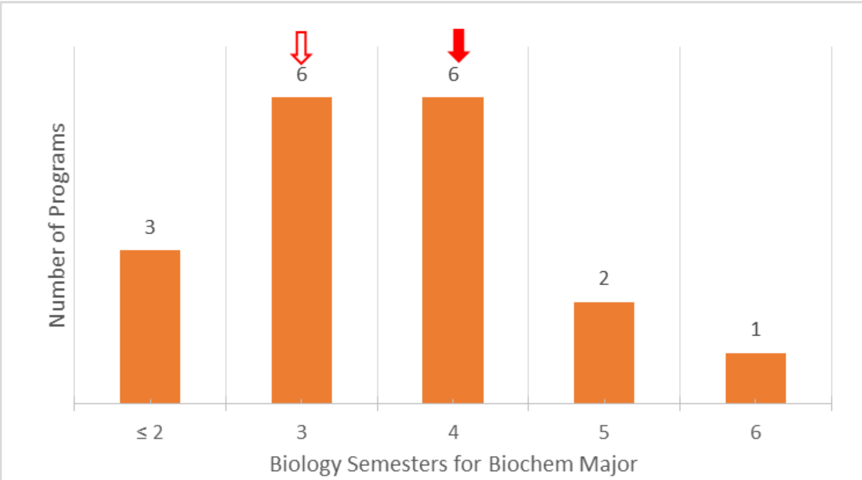

Figure 15: Number of total biology semesters required for biochemistry (or similar) majors. Open red arrow indicates Andrews-ACS Biochemistry degree; Filled red arrow is Andrews Biochemistry major.

Comparison between chemistry and biochemistry programs

While **Figure 13** shows that the overall credit counts (major plus cognate) of BS Chemistry and BS Biochemistry majors at baselined colleges overlap fairly extensively, comparing these two majors at the baseline schools yields several observations.

1) While overall credit counts are interesting to compare, it is also interesting to compare the BS Chemistry and BS Biochemistry majors at the same college. **Figure 16** shows a histogram of credit count differences between biochemistry and chemistry majors (biochemistry – chemistry) at the same school. It appears that there are *always* more credits for the BS Biochemistry (or equivalent) major than for the BS Chemistry major. The difference in required credits may be as small as one or as large as 15.
2) The bimodal distribution of differences in credit counts in **Figure 16** suggests that baseline institutions employ two general schools of thought about how to structure a biochemistry program.
    a. The "some extra work" category BS Biochemistry programs have ~5 credits (1-2 courses) more than BS Chemistry majors at the same college. Here, biochemistry seems to be a major parallel to chemistry, but without much extra coursework required: upper-division chemistry coursework is replaced more or less equivalently with biochemistry and biology coursework. Generally speaking, such a major would be less chemically rigorous.
    b. The "lots of extra work" category BS Biochemistry programs have 12-14 credits (3-5 courses) more than the chemistry major. This type of majors seems to approach biochemistry by adding rigorous biology requirements to a slightly lightened chemistry major. From a credit count and course-list perspective, the Andrews biochemistry majors (both ACS and non-ACS) fit into this second category. The only upper division chemistry course not required for BS Biochemistry is Inorganic Chemistry (4 credits), and a full 16 credits of biology are added to the major.

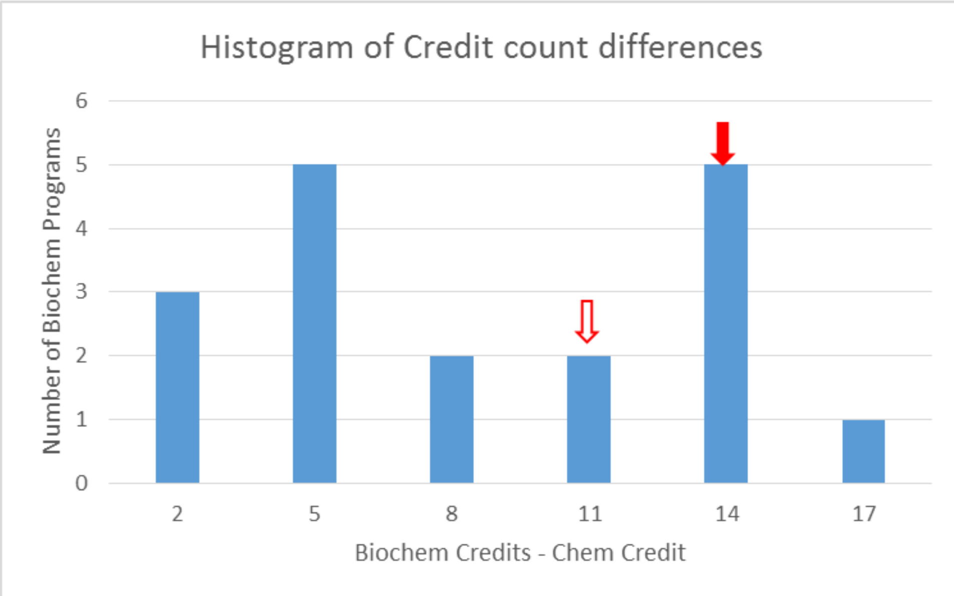

Figure 16: Histogram of credit count difference between biochemistry and chemistry majors at the institution. The x-axis label represents the maximum value: e.g., 8 means a difference of between 5.1 and 8 credits. Open red arrow indicates Andrews-ACS Biochemistry degree; Filled red arrow is Andrews Biochemistry major.

3) Another difference between BS Biochemistry and BS Chemistry programs has to do with cognates in mathematics and physics.
    a. Physics: Biochemistry is less likely to require calculus-based physics (7 of 16 require it) than Chemistry (10 of 16 require it). None of the 6 SDA biochemistry programs requires calculus-based physics. Andrews follows these generalizations, by allowing non-calculus-based physics for BS Biochemistry, but requiring calculus-based-physics for BS Chemistry.
    b. Mathematics: almost all Biochemistry majors require 2 semesters of calculus. Chemistry majors are more likely to require more semesters of calculus. At Andrews, both the BS Chemistry and BS Biochemistry majors require only two semesters of calculus.

Does the program successfully provide for the intellectual, social and spiritual development of students?

Intellectual Development: Student scores on nationally normalized ACS exams routinely meet our target of having at least half of the students earning at or above the 50^{th} percentile on exams. Students report being well-prepared for graduate school. Our students who pursue professional programs (medical, dental, pharmacy) do not report gaps in their preparation.

Spiritual Development: In our class-room experiences, our faculty set a spiritual atmosphere by beginning each lecture with prayer and sometimes a Bible verse. Drs. Nowack and Hayes make a special point to start many class with a short description of parallels (or contrasts) between topics in our discipline and spiritual or Biblical matters. Our basic goal is to model for our students that being successful in chemistry or biochemistry does not mean that we must be areligious. Additionally, the department and the chemistry club organize 3-4 vespers during the school year. Often our featured speaker is one of our faculty, a student, or someone who is part of the Andrews STEM family. This is a valuable opportunity for students, who attend these events, to see their teachers leading out in a religiously meaningful way.

Social Development: Students in the Department of Chemistry & Biochemistry socialize in the department itself and in the ChemClub. We schedule three main events through the school year that stimulate social involvement.

National Chemistry Week and ***Mole Day***: late October of every year
Soup Supper: early spring semester
Graduation Luncheon for graduates and their families: May of every year

The ChemClub also schedules several events throughout the year with faculty and departmental encouragement and support.

National Chemistry Week and ***Mole Day***: late October of every year
Club Ice Cream Feed: early fall semester
1-2 ***Friday Evening Vespers*** per semester
Enchilada Party: early spring semester
Various ***Community Outreach*** activities through the academic year

The faculty are actively involved in these events. The faculty participation and connection with their majors contribute to the positive assessment of the department by the department's graduates in senior exit surveys.

How does the number of swing and cross-listed courses compare with the number in benchmark institutions, and how is academic rigor maintained at the graduate level?

At the request of the CAS Dean and in consultation with departments whose students we serve, we removed all swing courses from our curriculum for the 2016-17 bulletin. The occasional graduate student from another department, (most often biology) who needs biochemistry, is served with a generic graduate level course currently available. We intend to create a specific graduate-level cross listing for biochemistry. Both graduate and undergraduate students would sit in the same course, but would be under different syllabi.

How rigorous is the curriculum for the preparation of graduates with skills necessary for a global workplace, who are able to adapt to changing environments and technology within their field?

The ACS CPT offers a white paper that outlines hallmarks of rigorous undergraduate programs in Chemistry (and Biochemistry). **Table 15** summarizes these hallmarks and the ways in which our program addresses them.

Table 15: Integration at Andrews of American Chemical Society Committee on Professional Training guidelines.

ACS Hallmark of Rigorous Programs	Exemplified at Andrews by…
Rigorous Curriculum: A rigorous undergraduate curriculum provides foundational and in-depth course work	
• that is appropriately balanced in breadth of content coverage and depth of treatment; and	Instruction, at what the ACS terms the "in-depth" level occurs in all sub-disciplines of chemistry, including biochemistry. Courses are thorough.

• that introduces students to an appropriately modern, quantitative, and mechanistic molecular perspective of the natural world.	Instruction and lab work is quantitative throughout the curriculum. General Chemistry, Quantitative Analysis, and Physical Chemistry are highly quantitative in nature. Organic Chemistry, in particular, is taught from a mechanistic perspective.
Student Competencies: A rigorous program develops students who are engaged in, and increasingly responsible for, their own learning. Students progressively develop throughout the curriculum the ability to:	
• search and utilize the primary literature;	This is part of our chemistry seminar sequence taken by juniors and seniors.
• analyze data and scientific arguments;	The scientific method and modeling of the natural world is introduced early in General Chemistry. Molecular and quantitative models for nature continue to be introduced and developed throughout the curriculum. Students generate and analyze data starting in General Chemistry, continuing in Organic Chemistry lab and Course-based Undergraduate Research Experience (CURE). Students generate and analyze complex data sets throughout the Analytical Chemistry sequence.
• synthesize and apply concepts from multiple sub-disciplines of chemistry;	Biochemistry and Inorganic Chemistry are especially well-suited to (and do) integrate concepts from multiple sub-disciplines of chemistry. Students in their chemistry seminar are expected to integrate learning from General Chemistry, Organic Chemistry and research experience (and more advanced courses) into their presentation.
• apply foundational and advanced concepts to new situations;	
• solve multi-step complex problems; and	The Analytical Chemistry sequence gives students hands-on exposure to solving problems that require multiple procedures be carefully conducted.
• communicate effectively in both written and oral forms.	Starting with Organic Chemistry (and CURE), students produce lab reports whose requirements increase through the program. Students in several upper division lab courses give a presentation in class.
Laboratory: In a rigorous laboratory course sequence, students:	
• progressively develop effective and safe chemical laboratory skills that require the use of modern methods and instrumentation;	Students in Chemical Separations and Instrumental Analysis use a wide variety of instrumentation. Starting in General Chemistry, students use UV-Vis to characterize samples.
• start with simple stepwise manipulations performed according to a prescribed sequence and progress to open-ended activities that require decision-making about appropriate experimental design and data interpretation/analysis; and	General Chemistry labs are highly descriptive. In Organic Chemistry and Quantitative Analysis, students need to THINK and analyze data while they work in lab. By the time students are in upper division analytical chemistry labs, they need be able to think on the fly: plan, execute, and analyze experiments and then adapt their data collection to maximize effective communication of results.

• produce organized, concise, and coherent descriptions and analyses of their experimental work through written and oral reports.	In General Chemistry, students complete pre-existing forms in most labs, writing more thoroughly for one or two labs. Starting in Quantitative Analysis and Organic Chemistry, students make detailed plans of their activity before lab and after lab write conclusions and lab reports. In the second semester of Organic Chemistry, students prepare a poster and video on an original research project. In Analytical Chemistry (and in Physical Chemistry II) students prepare thorough and complete written lab reports. In each of these courses, students also present oral reports of their labs.
Research: Undergraduate research that culminates in a capstone activity is often a mark of a rigorous program. Such research experiences are those where students conduct original work and demonstrate	
• mastery of independent thought;	Successful research students in our department take intellectual and task-level ownership of their research.
• self-direction of activities; and	
• application of an integrated, quantitative, and molecularly mechanistic view of chemistry.	Individual independent research (or CURE) topics vary, but students are generally encouraged to consider their projects at multiple levels.
Instructional Approaches: The ability to offer a rigorous program depends on a competent faculty with modern disciplinary expertise in chemistry content and in effective practices in undergraduate chemistry instruction. Faculty should engage regularly in activities that sustain their vitality as professional chemists such as attendance at seminars, colloquia and professional meetings, and workshops, and should consult the primary chemical literature on a continual basis. Faculty should	
• focus on creating learning environments that actively engage student participation;	Clickers are employed in General Chemistry, Organic Chemistry, and Biochemistry. Group work is used in Organic Chemistry and Analytical Chemistry.
• facilitate progressive development of student responsibility for learning throughout the curriculum;	Our program does this.
• demand critical thinking and multi-step problem solving in daily activities;	While there are some simplistic plug-into-formulae problems, most homework problems in General and Analytical Chemistry require attention to detail, careful thought and integration of several current concepts. Simply finding the right formula is rarely sufficient to earn high marks on homework. Paper homework keys in General Chemistry are weighted such that the proper *method* to solve the problem is worth much more than the right numerical *answer*.

• cultivate the development of an integrated understanding of chemistry throughout the curriculum;	Connections between chemistry and its applications in the broader world are made starting in General Chemistry: the Flint water crisis in 2015-16 made for an obvious connection of General Chemistry topics to the real world. In Organic Chemistry, students read *Napoleon's Buttons*, which helps students understand molecules that changed (or were important) in (western) history. Second semester Organic lab also provides CURE (course-based undergraduate research experience). In Instrumental Analysis and Chemical Separations students select and design analytical chemistry projects. Biochemistry is taught to convey a rich connection to how it all fits together.
• incorporate laboratory activities in which students define problems clearly, develop testable hypotheses, design and execute experiments, analyze data using appropriate statistical methods, understand the fundamental uncertainties in experimental measurements, and draw appropriate conclusions;	Starting with Quantitative Analysis, students are required to carefully consider the fact that experimentally measured numbers include quantitative uncertainty. Students are asked to make quantitative conclusions that support their data and reflect the uncertainty in their measurements. These skills are also developed in CURE and independent research.
• provide feedback on student work with attention to correctness, detailed commentary on language skills, and commentary on the precision and correct use of scientific language, chemical notation, and structural representation – all in alignment with accepted norms of the profession.	Advanced laboratory reports in Physical Chemistry II, Biochemistry, Quantitative Analysis, Chemical Separations, and Instrumental Analysis are evaluated with rubrics that include (and value heavily) competent written communication in our discipline. Providing this feedback in a timely manner (within 1.5 weeks) remains a challenge.

Student Assessments Rigorous assessments require students to demonstrate higher-order conceptual understanding and problem-solving skills. Rigorous exam formats include:

• A. free response items, including structure drawing in organic chemistry;

• B. items requiring multi-step quantitative reasoning;

• C. items requiring demonstration of a mechanistic understanding of reaction pathways and chemical processes;

• D. items that intellectually stretch students by requiring application of chemical concepts to new situations.

• E. may wish to use standardized ACS exams

	A	B	C	D	E
General Chemistry	65%	50%	0%	10%	Yes
Organic Chemistry	65%				Yes
Biochemistry					Yes
Physical Chemistry	0%	100%	0%	75%	Yes (3×)
Inorganic Chemistry					Yes
Analytical Chemistry	70%	70%	0%	20%	Yes

8. How do the various measures of outputs demonstrate the quality of the program?

The Department of Chemistry & Biochemistry is an undergraduate department providing bachelor degrees in chemistry and biochemistry. We offer research opportunities for our own majors as well as other majors.

Our department is on a positive trajectory of providing greater opportunity for students to engage in research with faculty. There are several factors that have enhanced our research effort: greater faculty involvement in research, greater student involvement in research, increased acquisition of modern instrumentation, and the establishment of Andrews ChemServices.

We are institutionalizing a culture of research through several mechanisms.

- creating and offering independent research courses (CHEM195, 295,) specifically designed to engage and give academic credit to college freshmen and sophomores, and high school students who are engaged in authentic research,
- converting second semester organic chemistry labs into a course-based undergraduate research experience (CURE), where all (~ 50-60) organic chemistry students conduct an original research project,
- offering summer research opportunities, for credit and/or pay, to undergraduate (or high school) students,
- providing research and development job opportunities for advanced students via Andrews ChemServices, and
- collaborating as Co-PIs/Supervisors on Master's thesis projects.

The quality of our department is shown by various measures of undergraduate program output, which may include: student exam scores on standardized exams, GRE and MCAT exam scores, number of students involved in research activities, number of graduates, and placement of those graduates in jobs, graduate schools, or professional schools.

Research Outcomes

Two types of research output are represented in **Table 16** showing student and faculty involvement in research activities. One measure of research output is the number of peer-reviewed publications produced by the department. This number is low for our six faculty, indicating the importance of teaching for this department. Another measure of research output is the number of talks and posters given by students at internal and external research presentation venues, as a way to involve students in the process of participating in and presenting research. This number demonstrates high involvement for our six faculty members. Especially when presented at outside venues, the research talks and posters provide a means to give visibility to Andrews University and its chemistry department.

Research Involvement of Students:

All students who are interested in research find faculty to mentor them. We provide opportunities from high school through postgraduate students, sometimes we are able to pay them from Undergraduate Research

Scholarships and Faculty Research Grants awarded by the Office of Research & Creative Scholarship (ORCS) and from external grants.

Table 16: Student and faculty involvement in research activities.

year	# of students involved in Research	# of posters/talks presented by students	# of students signed up for credit: 195/295/495	# of peer-reviewed publications	# of faculty reporting research
2015-16	26	14	14		6
2014-15	19	23	12	1	6
2013-14	10	27	8		6
2012-13	21	21	12	1	6
2011-12	9	10	1		6
2010-11	19	8	3	1	5
2009-10	12	2	7		3
2008-09	10	2	3		3
2007-08	11	8	2		3
2006-07	13	10	3		3

Performance on standardized exams

The ACS Exams Institute publishes exams in all areas of chemistry taught at the undergraduate level. The raw scores on these exams are nationally normalized. **Table 17** summarizes the performance of our majors on these nationally normalized exams. Every year, in General Chemistry, Organic Chemistry, and Quantitative Analysis, some of our majors earn scores at the 98th or 99th percentile. As discussed below, these are part of our program assessment targets and are assessed and reported yearly by our faculty.

Table 17: Summary of 2015-2016 ACS exam scores. The average raw score was converted to a percentile using the ACS normalization scores. The percent of majors meeting the defined target (≥ 50th percentile) is shown in the second row.

Gen Chem	Org Chem	Quant	P. Chem-Thermo	P. Chem-Kinetics	Biochem
Avg = 77.5 %ile 73% meet	Avg = 71 %ile 55% meet	Avg = 85 %ile 79% meet	No data 78% meet	No data 56% meet	Avg = 74th %ile 83% meet

Number of graduates

Figure 20 shows the number of graduates from our program.

Placement of graduates

A more detailed chart and discussion showing where our students go after graduating from Andrews is shown under question 10 in **Figure 20**. In summary, the majority of graduates from our program since 2000 matriculate as follows:

1. STEM graduate school

2. Medical School
3. Dental school
4. Other professional school: pharmacy, nursing, law school, etc

Student Learning Outcomes

University goals in **Table 18** connect the slogan, "Seek, Affirm, Change," to the student learning outcomes (SLOs) of the university. These goals guide our program learning objectives. **Table 19** correlates our departmental SLOs to the university goals.

Table 18: Andrews University Goals

Andrews University students will:					
Seek Knowledge as they		**Affirm Faith** as they		**Change the World** as they go forth to	
1.1	Engage in intellectual discovery and inquiry	2.1	Develop a personal relationship with Jesus Christ	3.1	Engage in creative problem-solving and innovation
1.2	Demonstrate the ability to think clearly and critically	2.2	Deepen their faith commitment and practice	3.2	Engage in generous service to meet human needs
1.3	Communicate effectively	2.3	Demonstrate personal and moral integrity	3.3	Apply collaborative leadership to foster growth and promote change
1.4	Understand life, learning, and civic responsibility from a Christian point of view	2.4	Embrace a balanced lifestyle, including time for intellectual, social, spiritual, and physical development	3.4	Engage in activities consistent with the worldwide mission of the Seventh-day Adventist Church
1.5	Demonstrate competence in their chosen disciplines and professions	2.5	Apply understanding of cultural differences in diverse environments		

9. How well are students meeting the program's learning outcomes?

Our learning outcomes will be very similar to those programs approved by the American Chemical Society. The advantage of this approval will be the uniformity of program curriculum for the chemical industry and feeding back into academia or graduate school. Individual program learning outcomes will vary somewhat with each institution. These are not readily available outside the college.

The American Chemical Society (ACS) provides some guidance

The ACS specifies that an approved program "provides both a broad background in chemical principles and in-depth study of chemistry…" Classes are divided into introductory (general), foundational level, and in-depth chemistry courses that are to include at least 400 hours of laboratory experience beyond introductory. The ACS also specifies areas that students should develop while in a program that go beyond standard concepts and laboratory practices. These include problem solving skills, chemical literature skills, laboratory safety skills, communication skills, team skills as well as ethics. As shown in **Table 19** our program's student learning outcomes seek to develop all of these areas in our students as they progress to become professionals. The same table correlates our SLOs with the university level goals. While one program may not meet every one of the university mission statement goals, the Department of Chemistry & Biochemistry has learning outcomes that do overlap with and further the university's mission.

Table 19: American Chemical Society skills correlated to the Andrews goals.

Andrews Chemistry & Biochemistry Learning Outcomes		ACS Skills Area	AU Goals
LO 1	**Knowledge**: Students will demonstrate a comprehensive knowledge and understanding of the identification and transformation of matter	Chemical literature, problem solving	1.1, 1.3, 1.5, 2.3
LO 2	**Research:** Students will be involved in the discovery of chemical knowledge	Chemical literature, problem solving, laboratory safety, communication, team, ethics	1.1, 1.2, 1.3, 2.3, 3.1
LO 3	**Communication Skills**: Students will effectively communicate (bio)chemical information to a diversity of audiences using a variety of formats.	Communication, chemical literature	1.3, 1.5, 2.5
LO 4	**Laboratory Skills with Safety and Environmental Stewardship**: Students will demonstrate a competency in common lab activities and instrumentation. Students will demonstrate accepted safe laboratory practices, waste management technology and the understanding the impact of chemical activities on the environment.	Laboratory safety, ethics, team, chemical literature, problem solving	1.2, 1.5, 2.3,
Aspirational Goals			
LO 5	**Integration of Christian Faith and Ethics**: Students will demonstrate a life of integrity, altruism, respect for others and the environment in their personal and professional lives consistent with the Christian faith	Team, ethics	2.3, 3.3, 3.4

LO 6	**Critical Thinking:** Students will apply the scientific method to rationally evaluate, integrate and communicate information and observations.	Problem solving, chemical literature, laboratory safety, communication, team, ethics	1.1, 1.2, 1.3, 1.5, 2.3, 3.1

The Department of Chemistry & Biochemistry's mission is to assist students as they develop analytical and critical reasoning skills (**LOs 1, 2, 6**), use fundamental chemical principles and computational methods (**LO 1**); prepare our chemistry and biochemistry majors to enter graduate school, professional school, the chemical industry, or the teaching profession. We strive to develop in our students an understanding of responsible, environmentally sensitive use of global resources (**LOs 1, 4, 5, 6**) and an understanding of the process of discovery and creativity in the research lab (**LOs 1, 2, 4, 6)**.

The curriculum map

Table 19 shows where the ACS outcomes are introduced and advanced in the program. **Table 20** shows a curriculum map of course versus program learning objectives (LO 1-4 from **Table 19**).

Table 20: Curriculum Map for the Chemistry and Biochemistry Courses

Legend · **X** student opportunity for outcome; · **A** in assessment plan in WEAVE.	CORE Departmental Curriculum										Upper Division Electives†					
	CHEM131-2 Gen Chem + Lab	CHEM231-2 Org Chem + LAB	CHEM200 Quant	CHEM210 Fr/So Seminar	CHEM311-2; 411-2 Jr & Sr Seminar	CHEM400 Separations	CHEM430 Instr Analy	CHEM431,41 Phys Chem I + Lab	BCHM421 Biochem I		CHEM415 Inorganic	CHEM432,42 Phys Chem II + Lab	BCHM422 Biochem II	BCHM430 Biochem Lab	CHEMx95 Indep Research	CHEM470; CHEM405; CHEM474; CHEM475
●**Knowledge**: Students will demonstrate a comprehensive knowledge and understanding of the identification and transformation of matter.	**X** **A**	**X** **A**	**X** **A**		**X**	**X**	**X**	**X** **A**	**X** **A**		**X**	**X**	**X**			**X**
●**Research**: Students will be involved in the discovery of (bio)chemical knowledge.					**X**										**X** **A**	
●**Communication Skills**: Students will effectively communicate (bio)chemical information to a diversity of audiences using a variety of formats.		**X** **A**	**X** **A**	**X**	**X** **A**	**X**	**X**	**X**				**X**		**X** **A**		**X**
●**Lab Skills with Safety and Env't Stewardship**: competency in common lab activities and instrumentation; use safe laboratory & waste management practices; understand impact of chemical activities on env't.	**X** **A**	**X** **A**	**X** **A**			**X**	**X**	**X** **A**				**X**		**X** **A**		**X**

LO1. Knowledge: Students will demonstrate a comprehensive knowledge and understanding of the identification and transformation of matter.

This chemistry goal corresponds with the Andrews Mission 1.1 Engage in intellectual discovery and inquiry and 1.5 Demonstrate competency in chosen discipline and profession.

Student knowledge is demonstrated by performance on nationally standardized ACS exams for many of the required courses. The department has set a target of 50% of majors will score at the 50th percentile or better on the standardized exams for General Chemistry, Organic Chemistry, Quantitative Analysis, Thermodynamics, Kinetics, and Biochemistry.

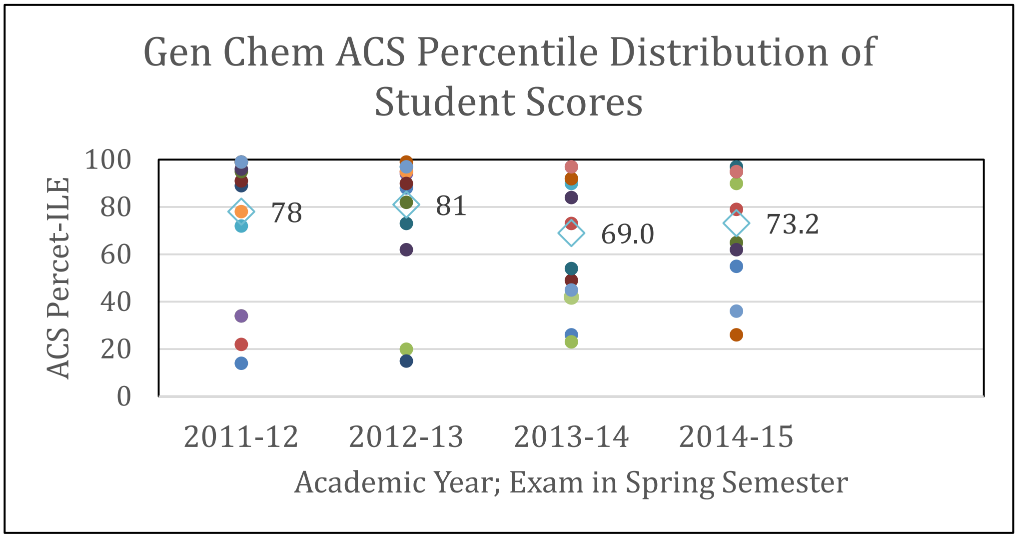

Figure 17: General Chemistry ACS Percentile distribution of student scores from the yearlong assessment given as a final exam in the spring semester.

Figure 17 gives a representative result for General Chemistry showing that students have met and exceeded the goal set. The assessment status for other classes entered into WEAVE are provided as a summary in **Table 23.**

LO2. Research: Students will be involved in the discovery of chemical knowledge.

This chemistry goal corresponds with Andrews Mission **1.1** Engage in intellectual discovery and inquiry, **1.2** Demonstrate the ability to think clearly and critically, and **3.1** Engage in creative problem solving and innovation.

A unique aspect of our research program is that it reaches undergraduate students who might not ordinarily participate in research. Because we are a small department dedicated to serving our students, our research program focusses on student participation and developing competencies in the unstructured research environment. While many of the research projects do not necessarily result in publications in peer-reviewed literature, the students usually present their results at an Andrews University research symposium; many present at other venues such as local, regional, and national meetings.

This program outcome for research is met when 50% of graduating majors participate in a STEM-area research project. Participation is self-reported or faculty-reported and can be met as part of a CHEM-295 or CHEM-495 research experience or independent from a formal class. As evident from the summary results in **Figure 18**, for three of four years, the target was met. When reviewing the 2014-2015 year, for example, 81% of students met this goal.

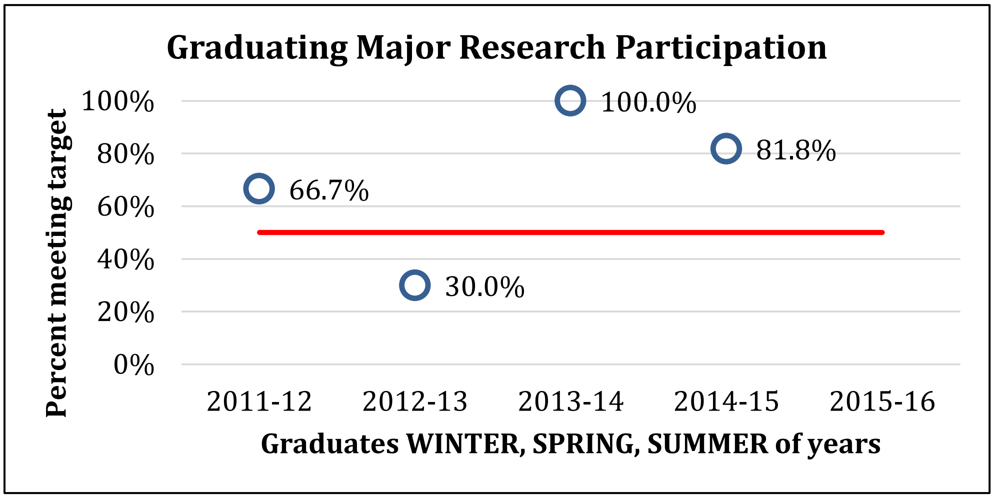

Figure 18: Research Participation of Graduates

LO3. Communication Skills: Students will effectively communicate (bio)chemical information to a diversity of audiences using a variety of formats.

This chemistry goal corresponds with Andrews Mission 1.3 Communicate effectively.

This learning outcome is met in both laboratory courses, where student lab reports are the major written communication vehicle, and through our seminar course sequence (CHEM311,312, 411,412). Rubrics are used to measure student skills in various aspects of the written document. Our seminar program is the major venue for oral communications. In the required chemistry seminar sequence, all students must generate one co-written (with one other student major) research paper and give, together, a 20-minute oral presentation the following semester. Two more 20-minute oral presentations are given in the senior year.

An example of the communication skills assessment in lab reports is found in the Quantitative Analysis lab report scoring rubric. See **Table 21**.

Table 21: Quantitative Analysis Report Rubric. Note the top row of the rubric maps the items in the rubric to learning outcomes and aspirational goals.

STUDENT	Title	Purpose Context	Chemical Reactions (NH3 + HCl ; HCl+NaOH	Apparatus drawing	Safety included	Procedure (pre-lab signature)	Conclusion (with value, method, possible errors)	Conclusion: "NH3";	Conclusion: Critical Thinking	Actual Observations and data in lab book	Masses used; Titration observations
1	1	1	1	1	1	1	1	1	1	NA	1
2	1	1	0	1	0	0	0	0	0	NA	1
3	1	1	0	1	0	1	1	1	0	NA	1
4	1	0.5	1	1	1	0	0	0	0	NA	1
5	1	0	1	0	1	1	1	1	0.5	NA	1

The data provided in **Table 21** represents a student by student evaluation of the written content of the report following a rubric where each specific item will get a zero or one (item present or not). Some of the items that are included for evaluation are purpose of the experiment, chemical reaction, apparatus, safety information, procedure, and conclusion. Some of the rubrics used to evaluate student work in other courses employ rubrics that are more sophisticated: in the case here, items are either in or not. Students are presented with a "typical" report-writing rubric to help them develop their lab reports. Each element in the score is placed in an aggregate area whose titles are in the column headings of **Table 22**.

For one report, the aggregate view of this data in **Table 22** shows the percentage of students meeting the aggregated item from the scoring rubric, color-coded with successes (green) to failures (red).

Table 22: Student status for meeting the aggregate areas from Table 21 in a given year. The rows are for individual students.

Communication aggregate	Critical thinking aggregate	Safety aggregate	Lab competence aggregate	Lab procedures	Analysis (math and spread sheet)
100%	100%	50%	63%	100%	75%
43%	50%	25%	38%	0%	0%
71%	50%	25%	25%	100%	88%
57%	25%	75%	63%	0%	38%
100%	25%	25%	63%	100%	63%

LO4. Laboratory Skills with Safety and Environmental Stewardship: Students will demonstrate a competency in common lab activities and instrumentation. Students will demonstrate accepted safe laboratory practices, waste management technology and the understanding the impact of chemical activities on the environment.

This chemistry goal corresponds with Andrews Mission 1.5 Demonstrate competence in their chosen disciplines and professions.

We use checklists of the various lab skills and/or laboratory final exams. Lab finals are developed in house and include questions on techniques, data analysis, safety, and/or waste management. The goal is at least fifty percent of departmental majors will score 60% or better on the exams and lab final assessments.

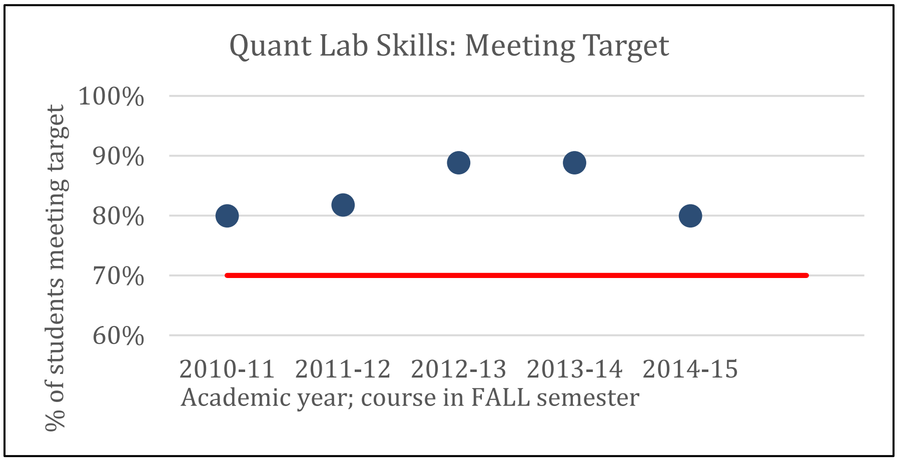

Figure 19: Quantitative Analysis Lab Skills Results

As an example of this target's results, we examine the Lab Skills Checklist as an assessment tool developed by the teacher for Quantitative Analysis. Each skill and each student is assigned a score based on the instructor's impression during the course of the semester with weighting toward the end of the semester. Students receive formative guidance during the semester. The Lab Skills checklist for this course evaluates the use of relevant lab equipment, development of relevant specific lab, computer analysis, and lab citizenship skills. These are illustrated in **Table 21** and **Table 22**. Total results of the Quantitative Analysis targets are shown in **Figure 19**.

Our assessment status with regard to established targets for the measures indicated are summarized in WEAVE and shown below in **Table 23**. Though there are a few data points missing at the beginning of the tracking period, the table shows that our department has grown to develop tools to keep and to report records and to successfully meet our department's goals. The time may have come to assess these goals with our results in hand to determine if the targeted values could be increased or otherwise changed.

Table 23: Assessment results of summary WEAVE data.

Measures	11-12	12-13	13-14	14-15	15-16
1: ACS Exam-General Chemistry (O:1)	met	met	met	met	met
2: ACS Exam-Organic Chemistry (O:1)	met	nd	met	met	met
3: ACS Exam-Quantitative Analysis (O:1)	met	met	met	met	met
4: ACS Exam-Thermodynamics (Phys Chem 1) (O:1)	not met	nd	not met	met	met
5: ACS Exam-Kinetics (Phys Chem 1) (O:1)	nd	nd	nd	met	met
6: ACS Exam-Biochemistry (O:1)	met	nd	not met	not met	met
7: Laboratory Final Exam - General Chemistry II (O:4)	nd	met	met	met	met
8: Organic Laboratory II Skills and Report Final- Spring (O:1, 3, 4)	nd	nd	nd	met	met
9: Laboratory Reports- Quantitative Analysis (O:3)	nd	nd	nd	met	met
10: Lab Skills Checklist- Quantitative Analysis (O:4)	met	met	met	met	met
11: Lab Skills and Report - Physical Chemistry I (O:3, 4)	nd	nd	nd	met	met
12: Lab Skills and Report - Biochemistry (O:3, 4)	nd	nd	nd	met	met
13: Senior Seminar I- Fall (O:1, 2, 3)	nd	nd	nd	nd	nd
14: Senior Seminar II- Spring (O:1, 2, 3)	nd	nd	nd	nd	nd
15: Research Participation (O:2)	met	not met	met	met	met

10. How successful are program graduates in seeking admission to graduate school or professional school? What is the level of satisfaction among students, alumni, and employers of alumni with the program and its outcomes?

Records from the Alumni Office are incomplete. The status of our graduates is shown in **Figure 20**. A clear area of improvement would be better tracking and contact with our graduates. The department has improved our capabilities recently.

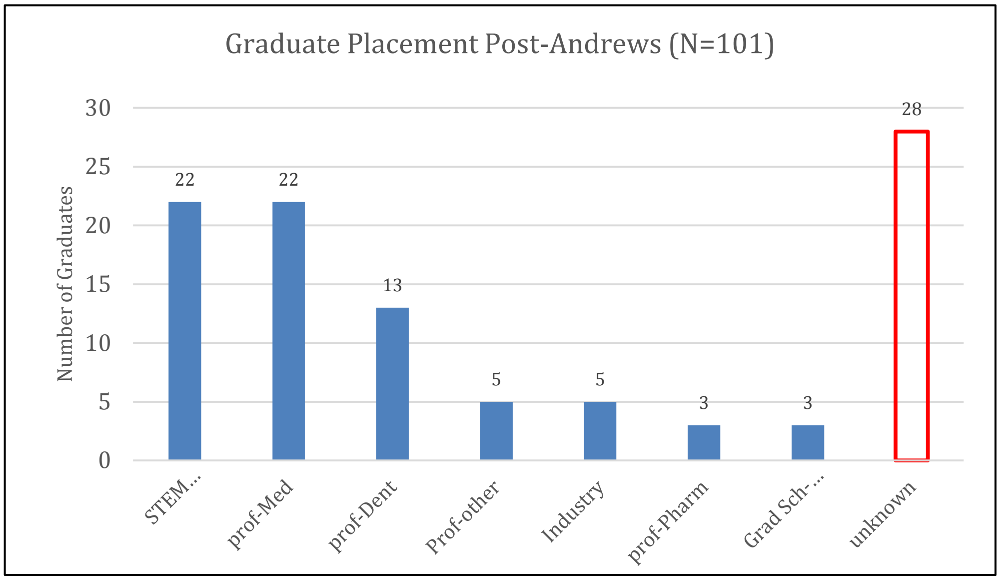

Figure 20: Placement of Chemistry and Biochemistry graduates.

Table 24: Post Andrews study acceptance rates. Much inference is difficult with small numbers.

		Applicants				Acceptances						
Year	Total graduates	Medical/ Physician Assisting	Dental	Pharmacy/ Nursing	Graduate school	Medical/ Physician Assisting	Dental	Pharmacy/ Nursing	Graduate school	Total: Applicants	Total**:** Acceptances	Percent Accepted
2008		2				1				2	1	50%
2009		3				2				3	2	67%
2010		1				1				1	1	100%
2011		1				1				1	1	100%
2012	3	0		1		0		1		1	1	100%
2013	11	0	3	0	1	0	3	0	1	4	4	100%
2014	4	2	1	1	1	1	1	1	1	5	4	80%
2015	11	4	2		2	2	1	0	2	8	5	63%
2016	9	2	4	0	1	2	4	0	1	7	7	100%

Recent records that we have on our graduates are more complete, and additional data can be pulled from the AMCAS database showing medical school applicants and their acceptances. These data are shown in **Table 24** and **Figure 21** along with other recent graduate activities and their acceptances. While the number of graduates that we have tracking data for is relatively small, we, nevertheless, conclude that we have positive outcomes for our students' success. Our students' overall acceptance rate to the programs indicated, since 2008 is 81%.

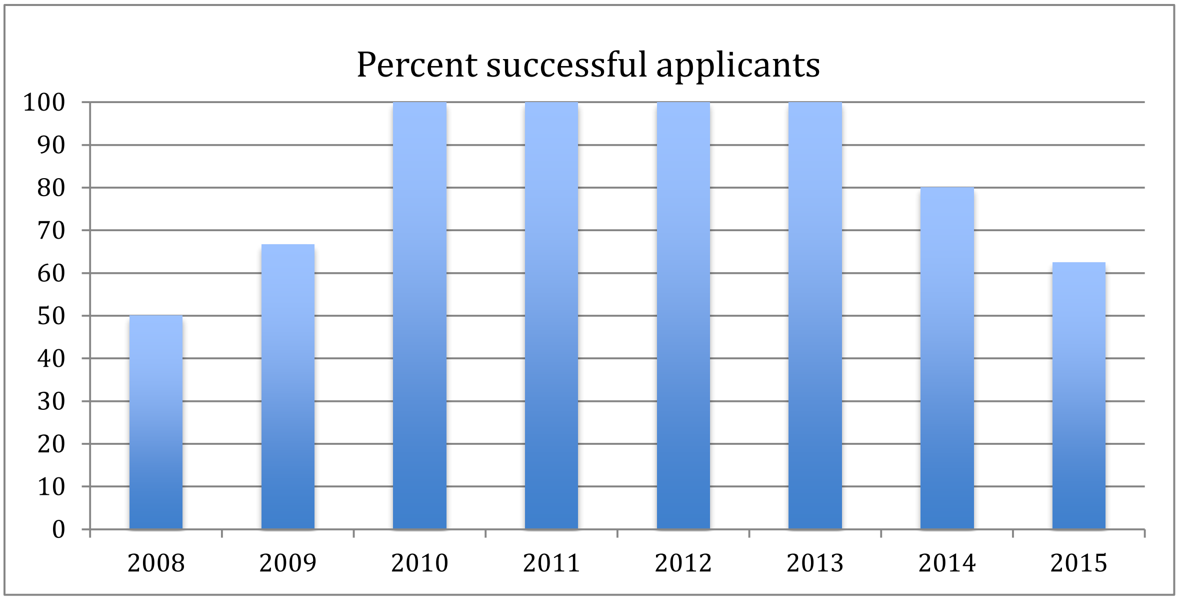

Figure 21: Successful post Andrews study applicants. Includes data from applicants to Medical School, Dental School, PA, Pharmacy, Nursing, and Graduate school programs.

Senior Exit Survey Results

The Chair of the Department of Chemistry and Biochemistry executed senior exit interviews for 2013, 2014, 2015 and 2016 academic years and queried 12 chemistry and biochemistry graduates. They were asked, in person, four simple questions.

What is the most positive thing about your experience?
What is the most negative thing about your experience?
What should be changed in the department?
What should not be changed in the department?

Their responses were classified by topic and by number of times the topic was mentioned. The top two or three responses to each question are listed below:

Most Positive	**Most Negative**
1. Good relations with faculty	1. Unhappy with chemistry seminar
2. Friends in department	2. Poor lab equipment; disorganized
3. Small class size	

Don't Change This	Change This
1. Jobs in department	1. Seminar
2. Research	2. Nothing

The single most common response of all the responses to all four questions was the #1 response in the *Most Positive* column: "Good relations with faculty." The graduates believe that our faculty take a sincere interest in their academic, social and spiritual welfare. This conclusion is supported by the Senior Survey Results for 2013 from the Office of Institutional Effectiveness. Comments from that survey included: "The number of faculty willing to help their students was good…" and "Family atmosphere…"

The departmental survey revealed that the students want the department to continue to offer jobs to the majors and continue to be active in research.

The most negative comments, which are similar in both the *Most Negative* and *Change This* columns concerns the chemistry seminar class. The seminar series, CHEM 311/312/411/412, is a set of 0.5 credit classes spread out over 4 semesters that seeks to prepare our graduates to receive, interpret, and communicate chemistry information in a variety of formats along with learning job skills and job hunting skills. Informal discussions with students about the class indicate that the students are unhappy with the low credit value of the class and the diffuse nature of the class: that is, the requirement being spread out over four semesters.

The department is responding to the negative seminar assessment by renovating the class to address the student concerns. The content of the class will approximately remain the same, but scheduling and credit value will be modified to reflect student concerns. The renovation will also affect faculty teaching load. The renovated class will be presented to the appropriate university committees this fall and implemented in the fall of 2017.

11. How have the above data contributed to decisions for program improvement? What impacts have these evidence-based changes had on student learning and student success?

The curriculum of our program is fairly prescribed by the ACS CPT. We do not have a lot of leeway to make substantive content changes to our program. Some methods of delivery and packaging have been modified. One major program change we made in 2012 was the addition of the upper division analytical chemistry sequence as a requirement for the Biochemistry major.

We have modified the management of our General Chemistry course in response to score differences between students attending only three days per week. See **Figure 8** and the entire General Chemistry discussion in section 7 of this report.

In 2014, a survey was given to students regarding our seminar program (CHEM311,312, 411,412). This survey and subsequent conversation by faculty and students was the springboard to develop our understanding of how we implement this educational experience. Based on the feedback from students and the discussions in the department, a new seminar course will be designed to serve as a capstone experience of our program where the students integrate library research skills with sophisticated communication of chemical information skills while showcasing laboratory research they may have been involved with.

The ACS Committee on Professional Training determines that the rigor of a chemistry program is defined by its student research reports among other things. Our program used to require such reports of our students, but we have not required this recently. This would be an excellent way to reinvigorate the rigor and value of our program: a well-written research report documenting the student's experience evaluated with a robust and well-designed rubric by the faculty would be of great benefit to students and to assessment of our program.

CRITERION 3: Financial Analysis

12. What is the relationship between the cost of the program and its income and how has that been changing over time?

Financial Contribution of the Department.

We used two metrics to report cost and income: chemistry's percentage of STEM contribution to the university's bottom line and chemistry's percentage of STEM contribution to the university's overall undergraduate credit count. **Table 25** shows the department's contribution to the bottom line for the fiscal years from 2005 to 2013. Data has not been available from the dean's office since that date.

Table 25: Chemistry Department Percentage of STEM Contribution to Bottom Line.

Year	Dept FTE	Total Credits	Student: Faculty	Chemistry Income	Cost	Chemistry Contribution to Bottom Line	Total STEM Contribution to Bottom Line	Chem Dept % of STEM contribution to Bottom Line
13-14	5.5	2,581	15.1 : 1	Information not available				
12-13	5.5	2,478	14.5 : 1	$1,570,719	$614,373	$956,346	$3,268,375	29%
11-12	5.5	2,334	13.7 : 1	$1,270,391	$581,154	$689,237	$2,816,722	24%
10-11	5.5	2,355	13.8 : 1	$1,258,820	$598,029	$660,791	$2,928,577	23%
09-10	5.3	2,310	14.2 : 1	$1,228,465	$596,133	$632,332	$2,892,358	22%
08-09	5.3	1,986	12.2 : 1	$1,026,296	$469,399	$556,897	$2,960,206	19%
07-08	5.3	2,109	12.9 : 1	$1,027,304	$511,208	$516,096	$2,450,924	21%
06-07	5.3	1,956	12.0 : 1	$911,297	$476,002	$435,295	$2,094,668	21%
05-06	5.3	2,086	12.8 : 1	$896,377	$487,339	$409,038	$1,997,113	20%

Beginning in the year 2008-09 through the last year such data was available 2013-14, the total number of credits generated by the departmental classes increased annually. This increase allowed for greater efficiency with a FTE student to FTE faculty ratio from 12:8:1 in 2008-09 to 15.1:1 in 2013-14. **Figure 22** shows that ultimately, the increased efficiency allowed the department to contribute nearly 30% of the positive bottom line for the STEM division. **Table 26** shows that this makes the Department of Chemistry & Biochemistry the second largest contributor within the division. The income generated by the department exceeded costs during all years, and the trend has been that our department is increasing its percentage contribution to the overall bottom line for the College of Arts and Sciences.

Table 26: Department Percent Contribution to University Bottom Line—from Dean's Productivity Report.

Year	Biology	Chemistry Biochemistry	Engineering Computer Science	Mathematics	Physics
12-13	35%	29%	-4%	28%	12%
11-12	39%	24%	-15%	39%	12%
10-11	40%	23%	-6%	35%	9%
09-10	37%	22%	0%	35%	6%

Year	Biology	Chemistry Biochemistry	Engineering Computer Science	Mathematics	Physics
08-09	42%	19%	0%	34%	6%
07-08	23%	18%	0%	30%	13%
06-07	22%	15%	0%	24%	10%
05-06	18%	14%	0%	26%	11%

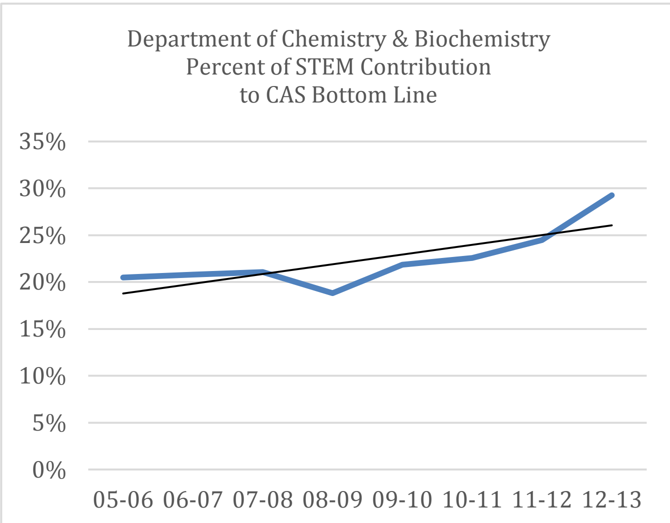

Figure 22: Percent of STEM contribution to bottom line.

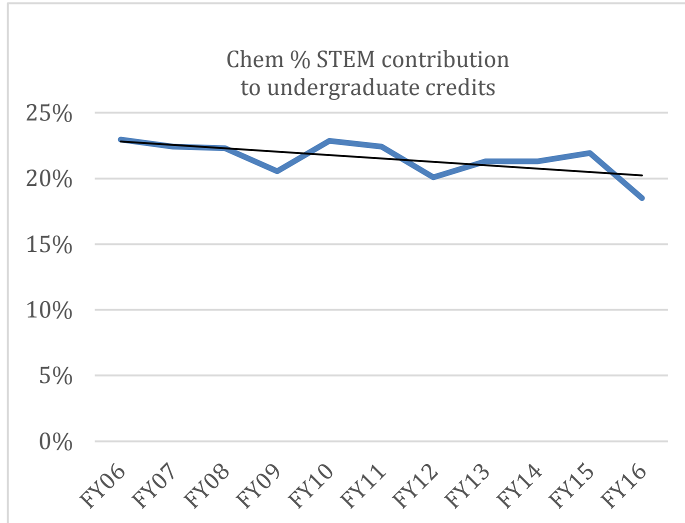

Figure 23: Percent of STEM contribution to undergraduate credits.

Contribution of the Department to Credit Generation

Using readily available current data, the percent contribution of undergraduate credits by the Department of Chemistry & Biochemistry relative to the total number of STEM undergraduate credits is shown in **Figure 23.** The trend is slightly downward with a relatively steep decline recently, which can be attributed to the addition of the Department of Agriculture to the STEM division as well as the number of credits generated by a growing Department of Engineering & Computer Science.

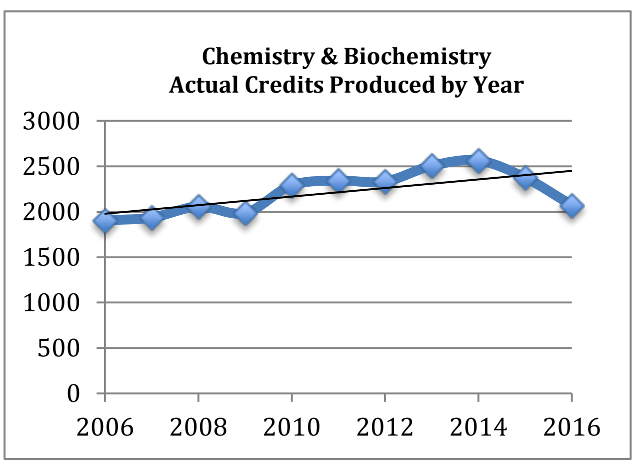

Figure 24: Department credits produced by year.

Again, using readily available current data, the actual number of credits produced per fiscal year is shown in **Figure 24**. The steady growth during the early 2010s reflected the growth in the university's overall student population. The steep drop during the 2014-16 years is attributed to the overall decline in the number of students enrolled in the entire university and especially to the decline in the number biology majors, whose course of study requires them to take five semesters of chemistry.

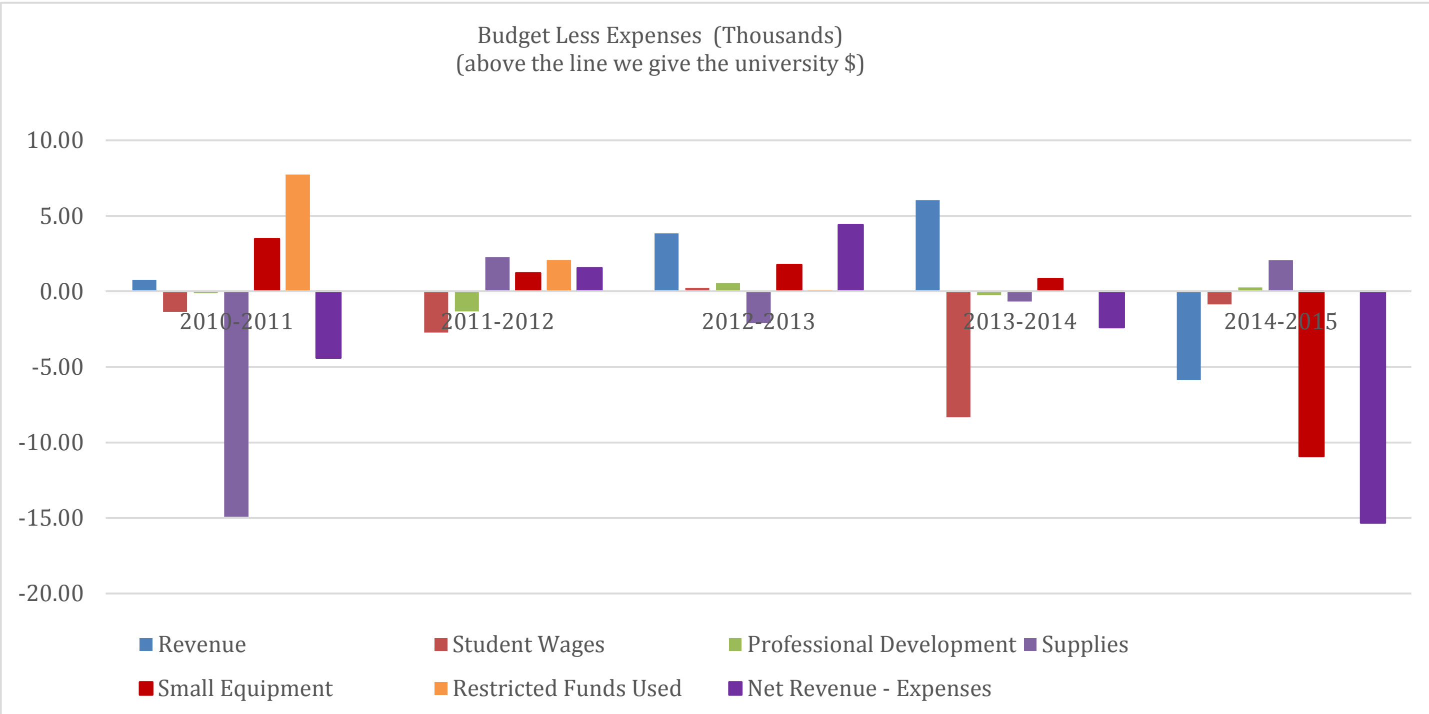

Figure 25: Net revenue for the department.

The departmental budget is the foundation for much of what impacts the student experience in chemistry. Fortunately, the budget is adequate to create that impact. For the most part, our budget matches our needs. Either the excess expenses (below the line in **Figure 25**) were covered by other funds or the expenses were applied to the budget in a manner that was unexpected and untimely.

Table 27: Income vs. Expense ratio for CAS and the department.

FY	CAS Average	CHEM
2014	NA	2.08
2013	2.02	2.31
2012	2.01	2.18
2011	2.04	2.10
2010	2.00	2.05
2009	2.28	2.18
2008	1.95	2.01
2007	1.95	1.91
2006	1.80	1.84

The office of the Dean of the College of Arts and Sciences generates a metric value called the "Income/Expense Ratio." This ratio is used by the dean to provide a management target to evaluate departments. As shown in **Table 27**, the Department of Chemistry & Biochemistry has exceeded the CAS average nearly every year. The administrative assistant from the dean's office at the time is quoted as saying, "For Chemistry, your income to expense ratio has been very healthy over the years."

13. What is the (financial and other) impact of the program on the University and, based on trends, how is that likely to change in the future? How adequate is the University support to maintaining the health of the program?

American Chemical Society Approval

Since 1976, the approval of a chemistry (and now biochemistry) curricula by the American Chemical Society (ACS) has been the single greatest positive impact that the Department of Chemistry & Biochemistry has had on the university. The ACS is the largest scientific organization in the world with nearly 157,000 members. Its approval of programs in US colleges and universities verifies to national and international institutions that the programs meet world-class standards of curriculum, faculty, facilities and instrumentation.

The ACS-approval of the chemistry and biochemistry degrees creates and sustains a confirmed foundation of excellence. The STEM Division departments, through conversations between the STEM chairs and the chemistry chair, have confirmed the positive effects on their majors, graduates and programs.

Chemical Engineering

The new chemical engineering concentration in the Department of Engineering & Computer Science relies extensively on the quality of the chemistry program in our department.

Quality of Instruction

The Department of Chemistry & Biochemistry is the academic home to a group of excellent instructors. Five of the six full time professors have received significant awards for teaching quality. The expertice of the instructors crosses the entire range of chemistry subjects: general, organic, physical and biological chemistry. For example, Dr. Lisa Ahlberg received the Andrews University Student Association Teacher of the Year Award in 2016.

As noted in the previous section, the Department of Chemistry & Biochemistry has a positive impact on the financial integrity of the university. Both the short term and the long term trends for the positive impact appear to be stable. The student-credits generated by the department's academic activities exceed the target set by the Dean of the College of Arts and Sciences by a significant margin. For example, in FY 2013, the department generated an average of 420 credits per full-time-faculty equivalent (FTE). The target value from the College of Arts and Sciences is 240 credits per FTE. That puts Chemistry in the top 5 departments in the College of Arts and Sciences.

Adequacy of support

The Andrews University administration has been highly supportive of the Department of Chemistry in two especially important ways: facilities and instrumentation.

Air-handling system renovation and upgrade. Sometime during the mid-1980's, the original air handling system for the entire Science Complex (Price Hall, Haughey Hall and Halenz Hall) had a catastrophic failure during a severe winter storm. Rather than repair the system and restore the original functionality, the decision was made to shut off and insulate the floor-mounted outside-air intakes. This solved the cause of the catastrophic failure, but seriously degraded the air-quality of Halenz Hall which was dependent on a continuous supply of fresh conditioned air to replace the indoor air that was removed during the ordinary and proper use of the chemistry fume hoods. Thus, for over 25 years, Halenz Hall occupants were exposed to excess chemical fumes. The administration was aware of the degraded air quality. Only as air quality standards changed and the public awareness of the hazards of chronic chemical exposure did the issue become a complelling priority to remediate.

Beginnng in 2010 and over the course of four summers, the University significantly upgraded the air handling system in Halenz Hall. The improvements were funded out of the annual capital budget. The approximate order of the renovations is shown below in **Table 28.**

Table 28: Major Renovation Stages--Halenz Hall

Summer of:	Renovation Action
2010	Roof top air-handling
2011	2nd and 3rd floor stockrooms
2012	Second and third floor hoods only
2013	First floor and completion of third floor organic labs

The approximate cost of these renovations was $3.7 million.

During the same time period, the chemistry faculty evaluated the quality and functionality of the scientific instrumentation in the department. Many of the instruments had served our department well beyond their end of life. Some could not be repaired because parts were not available. The faculty prioritized the needs and presented them to the administration. Over the four years, five crucial instruments (**Table 29**) were purchased that covered the entire range of technologies used in modern chemical labs.

Table 29: Instrumentation Upgrade and Maintenance Schedule

Year	Instrument	Cost
2011	Agilent High Performance Liquid Chromatograph	$48,250
2011	Cary Eclipse Fluorescence Spectrophotometer	$18,700
2012	Agilent Gas Chromatograph and Mass Spectrometer	$133,425
2013	Perkin-Elmer Optima 8000 ICP-Optical Emission Spectrophotometer	$55,900
2014	Nicolet iS50 FT Infrared Spectrophotometer	$31,800
	Total	$288,075

For each instrument purchase, we partnered with the administration to fund, in part, the cost from our restricted funds. The restricted funds are contributions donated by our alumni and friends. As **Figure 26** shows, the contributions peaked about the time our need was the greatest.

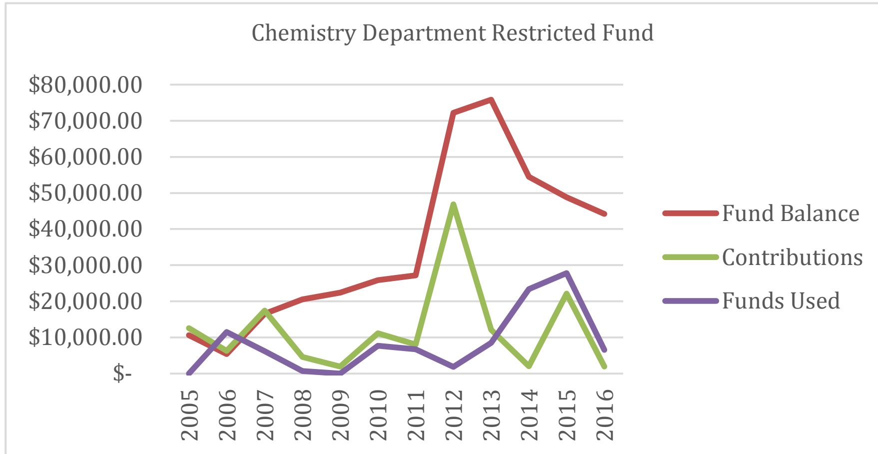

Figure 26: Chemistry Department Restricted Fund Balance and Contributions

In terms of renovation of old spaces, the physical infrastructure support of the department by the university has been adequate over the last five years. The air-handling renovation has a projected lifetime of 30 years so that is no longer a concern other than on-going maintenance of the equipment. However, three of six faculty members do not have dedicated research space. The university's support has not been adequate in this respect. The lack of space has had a negative impact on research productivity and undergraduate research mentorship.

The support by the administration and alumni in the instrumentation suite has been adequate over the last six years. By 2009, the instrument suite of the department was facing a serious deficit. The instruments at that time, other than the NMR and UV-Vis acquired in 2001, were no longer current technology, or were broken without possibility of repair, or simply not available. Some entire classes of instrumentation were not represented. The current suite of instruments, although missing a couple of important classes of instrumentation, such as a high speed ultracentrifuge and a programmable fraction collector, is adequate for now and represents the most complete set of instrumentation in Adventist higher education in the world.

The support by the administration in the area of human resources is inadequate. The faculty, the most important and most expensive resource in the department and university, are now occupied in managing and executing routine chemistry laboratory inventory, experiment materials preparation, safety training, hazardous material handling, teaching assistant training, and teaching assistant management. Many schools of our size have a dedicated full-time staff member, typically at the Masters level of education, to accomplish the tasks listed. The absence of such a position in our department was noted in the ACS program approval letter of 2015, where the CPT (Committee for Professional Training) committee wrote,

> **"Support staff. According to Item 3.4b of the periodic report form, the department does not have a stockroom manager. The Committee encourages you to discuss this staffing need with the administration to identify a mechanism to fund this important position."**

Beyond a revision in the classification of certain classes in the major, the comment above was the only comment of concern by the Committee for Professional Training. Seventy-five percent of baseline departments have a lab manager—including some of our sister SDA institutions. Thus, the data suggests that the support offered by the university administration is sufficient for capital expenditures, but lacking in the area of human resources. Conversations with Dr. Keith Mattingly, Dean of the College of Arts and Sciences, have been unable to find funding for a full-time position of lab manager. Yet, a lab manager is a significant unmet need in the Department of Chemistry & Biochemistry.

CRITERION 4: Strategic Analysis

14. Describe the strengths of the program.

What examples of exemplary performance does the program demonstrate?

Faculty and Staff Strengths

- All six full time faculty members have a PhD in chemistry or biochemistry.
- Five of six faculty have won external or internal recognitions.
  - Dr. D. David Nowack was recognized by the AUSA as advisor of the year for 2004-05.
  - Dr. Desmond Murry was recognized by the Michigan Science Teachers Association (MSTA) as the College science teacher of the year in 2012.
  - Dr. David Randall was the CAS STEM division awardee of the Daniel Augsberger award in 2013
  - Dr. Ryan Hayes was the CAS STEM division awardee of the Daniel Augsberger award in 2014. Dr. Hayes was also awarded the CAS Research Mentor of the Year 2015-16.
  - Dr. Lisa Ahlberg was the AUSA-selected teacher of the year for the 2015-16 year.
- Drs. Hayes, Ahlberg, and Randall have a combined 23 years of industrial experience.
- New hires from 2009 and 2010 are up to speed and fully contributing to department and university maintaining full teaching and advising loads while participating in research and committee assignments.
- Dana Johnston, the administrative assistant of the department, has an MS in physical chemistry, and combines her knowledge and skills in chemistry to enhance the operation of the department. In the absence of a stockroom manager, she is our support in inventory and hazardous waste management. She has also proved invaluable in managing well the resources for the department—budgetary as well as chemical and supply resources. Her background in running a small business has also benefited the department as we have taken on the responsibilities for Andrews ChemServices, our in-house dendrimer business.

Curriculum Strengths

- ACS approval since 1976. Andrews University Department of Chemistry & Biochemistry is the only SDA college department whose program is approved by the ACS. Other colleges (Southern) claim that students can meet the “curriculum recommendation” of the ACS by taking certain courses. But the ACS offers only full “program approval.” Southern Adventist University is not listed by ACS.
- The American Chemical Society (ACS) is one of the largest professional organizations in the world. The ACS attempts to serve the interests of the chemical manufacturing and industrial research. They publish some of the highest impact American chemical journals. The ACS concerns itself with chemical education from middle school through graduate school. The ACS has a Committee on Professional Training, which defines curricular requirements for departments to have an ACS approved curriculum. This curriculum is a rigorous training in chemistry that aims to ready students for a career in chemistry or to move on to graduate school in chemistry. ACS approval represents more than a list of classes, it recognizes that a solid training in chemistry requires physical and administrative infrastructure to be in place: contact

hour limits (which are no more stringent than Andrews working policy) to allow faculty time to develop courses; a research program; and instrumentation requirements.

- The approval process is somewhat arduous, for in addition to requiring classes ACS approval requires a substantial administrative commitment in the form of facilities and instrumentation. Thus, partner institutions who claim their curriculum matches that mandated by the ACS's CPT are rather missing the point of ACS approval: the lab facilities and instrumentation may be subpar; the faculty may have no encouragement to engage in research; there may be no allowance for faculty to have time in their schedules to develop student relationships. Again, at Andrews the ACS mandated faculty load is equivalent to the Andrews working policy. However, this is not the case at all schools.
- From a student perspective, ACS approval of our program helps students seeking to further their careers in science and engineering establish that their chemical training was rigorous.
- This rigorous training has served the SDA church in the US. In the chemistry faculty of US SDA colleges, Andrews counts at least 13 graduates. Considering the relatively small enrollment of Andrews, and in our department at Andrews, compared to some of the larger SDA colleges, this is remarkable. Andrews graduates were sufficiently interested and capable at chemistry to go on to successfully complete PhDs and further they retained a substantial commitment to the church sufficient to return to teaching in our institutions.
- Our department offers many “service” classes that are required by other programs. General Chemistry (CHEM131-132, 2 semesters), Organic Chemistry (CHEM231-232 and CHEM241-242, 2 semesters), and Biochemistry (BCHM421, 1 semester) are required training for pharmacy, medical and dental schools. General Chemistry (2 semesters) also serves as a prerequisite for physical therapy, while Introduction to Chemistry and Biochemistry (CHEM110 and BCHM120, 2 semesters) is a required class for many allied health degrees such as nursing, dental hygiene, nutrition, agriculture, education, etc. General Chemistry is also required for engineering, biology and physics majors. As do many other STEM departments, we provide an Andrews Core Experiences class option in Consumer Chemistry (CHEM100).
- Our department currently offers students the option of pursuing a degree whose curriculum is approved by the ACS as an emphasis (or concentration) that can be added to either our chemistry or biochemistry majors. Majors in our department who chose not to pursue the ACS degree as well as students in our pre-professional service courses (General Chemistry, Organic Chemistry, Biochemistry), benefit from the rigor with which Andrews has historically approached undergraduate chemical education.
- Our chemistry and biochemistry majors average a 50 percentile or greater score on ACS nationally standardized exams for all chemistry and biochemistry classes that use ACS exams for assessment. The average ACS General Chemistry scores for all students and sections of General Chemistry is above 60 percentile.
- The “DFW rate” is the percentage of students who score a D or F for the final grade, or withdraw from the class. Many universities have DFW rates from 20 to 50% for General Chemistry. DFW rates for our General Chemistry range around 10% for CHEM131 and around 5% for CHEM132. These low rates highlight the successful nature of our approach to operating this first year science class.
- A new Biotechnology Major recently developed in partnership with Biology (in 2015) is not assessed herein.
- Innovative course development: Medicinal Chemistry (CHEM405) and Chemistry Seminar (CHEM311,312,411,412).

Equipment and Physical Infrastructure Strengths

- Instrumentation: We have a strong suite of modern analytical instruments. Many of these have been purchases in the last seven years. All used in teaching (CHEM131, 132, 200, 231, 232, 400, 430, 441, 442 along with BCHM430) and research. All systems that require computers for operation have been upgraded to Windows 7, which is the most modern operating system available for these instruments.
    - Fourier Transform Infrared (FTIR): Nicolet spectrometer, acquired 2014.
    - Waters PrepLC 4000: acquired used in 2014.
    - ICP-OES: Atomic Emission spectrometer: Perkin Elmer; acquired 2013.
    - Buchi Rotovap R-15 (20 L) system with chiller: acquired in 2013.
    - Ocean Optics Portable Spectrometers: Five operational systems, acquired 1998-2013.
        - USB2000 system (2x), Red Tide USB650 (2x), PC2000 (1x)
    - GC-Mass Spectrometer; Agilent 789, acquired 2012.
    - Fluorescence spectrometer with plate reader: Varian Eclipse; acquired 2010.
    - 400 MHz NMR: JOEL Eclipse-400; acquired 2001.
        - Functional, but aging and will require replacement in next 10 years.
    - Electrochemistry potentiostat: Cypress Omni101; acquired in 2008.
    - UV-Vis-NIR spectrometer: Varian Cary 5000; acquired 2005.
    - Raman spectrometer, RAMAN Systems 2001; acquired in 2004.
    - Nd:YAG pulsed laser, Continuum MLII; acquired in 1997.
    - 28 analytical balances; acquired in various years from 1990's to 2015
    - pH Meters (Six high quality instruments, various years of acquisition, all but two were purchased less than 5 years ago).
    - Eight rotovaps acquired in various years. 6 in teaching labs and 2 in research labs.

- Lab, Stockroom, and HVAC system renovation: 39 fume hoods have been installed in the teaching and research labs along with the two stockrooms. These essential components of a chemistry department were completely renovated in the summers of 2010 through 2014. These renovations moved building ventilation needs into best modern practice and updated aging departmental and physical infrastructure. Construction during these five summers restricted faculty summer time activities, such as research, but brought the department into safe operating practices with a computer controlled HVAC system that regulates air flow to keep students safe while saving energy through careful ventilation control. A heat exchanger was installed in 2015 on the top of Halenz Hall to recover the lost energy and save money on energy expenditures.
- Solid building construction. Low building vibrations facilitate sensitive weighing and delicate instruments (NMR).

Enrollment Strengths

- Our departmental major (chemistry and biochemistry) enrollment has been growing or flat over the last few years, while enrollment in other CAS departments has fallen.

- Enrollment in our service classes continues at record high levels, especially for General Chemistry.

Research Involvement

- High involvement of faculty and students in novel research projects.
- Over the past two years, all faculty members are participating in research projects here in the department or in collaboration with other institutions, a first for this department in many decades.

University Service

- SciFest: All faculty have participated in various ways since the inception of this program.
- Recruiting: David Nowack has visited Adventist academies in the eastern U.S. providing chemical demonstrations and recruiting activities.
- Committees: All faculty have served or currently serve in a variety of committees on campus including Faculty Senate, Pre-professional Recommendations Committee, Faculty Policy, Undergraduate Council, National Scholarship committee, etc.

Community Service

- A faculty member has taught a mini-course at Ruth Murdoch Elementary School for the past four years.
- Additionally, faculty members have been involved in various chemistry activities in area schools: Science Fairs, chemical demonstrations at the school, and demonstrations performed here at Andrews University. Area schools that have benefited from Andrews chemistry faculty participation include Andrews Academy, Village SDA Elementary School, Ruth Murdock Elementary School, South Bend Junior Academy, Grand Rapids Junior Academy, Greater Lansing Adventist School, Eau Claire SDA school, Hartford Woodside Elementary School and Benton Harbor area schools. In addition faculty have been involved in presentations, programs, and leadership at a variety of churches in the area including Pioneer Memorial Church, Village SDA Church, Eau Claire SDA Church, Dowagiac SDA Church, Edwardsburg SDA Church, and the Southeast Asian SDA Church
- Berrien County Forensic Lab (BCFL): has served the community since 1972. The lab analyzes drug samples for law enforcement agencies throughout and beyond Berrien County. Since the 1970s, Berrien County has contracted with Andrews University to operate the laboratory where the analyst uses modern chemistry analytical methods to assess samples provided by law enforcement officers. We have partnered with local instrument supplier LECO (St. Joseph, MI) to provide a Gas Chromatography time-of-flight Mass Spectrometer. The presence of this lab on campus and our forensic chemistry course (CHEM410) provide students with the opportunity to learn more about the details of this application of analytical chemistry. It also provides the opportunity for jobs or internships, including for our current chief analyst, John Rorabeck.
- RESA Grade 10 and Grade 12 chemistry courses. Grade 12 RESA chemistry students perform a research project, and submit a poster and presentation describing their results. This research effort represents a part of the institutionalization of a culture of research throughout our department, as discussed earlier under Question 8. Grade 12 RESA chemistry students have the option to earn college credit for their research as well.

Public Science

- Public science is an intentional aspect of our program that proactively engages the public in chemically relevant topics of interest using basic modern communication tools. We intentionally and routinely use newspapers, email, Twitter, Facebook and You Tube to micro-target specific potential audiences to attend, view or read about our guest lecture seminars and webinars. These audiences include other university departments, high school students, department alumni, SDA high schools and colleges, and local and statewide science teachers, and media.

Non-profit Entrepreneurship

- Andrews ChemServices (AuCS): has operated out of the department since 2013. This is a small business that the department operates to provide polymer-based nanomaterials, called dendrimers, for research and educational use. AuCS provides work opportunities for approximately two students per year in manufacturing, analysis, and bottling. AuCS has a website (http://www.andrewschemservices.com/) and sells to a major chemical distributor (Sigma Aldrich). These materials also provide research materials for faculty and student projects. AuCS has an agreement with Starpharma (Melbourne, Australia) to manufacture, distribute, and sell PAMAM dendrimers which was signed in March 2013. Collaborative work with Starpharma began in December 2010 and grew into the business opportunity that it is today.

15. Describe the weaknesses of the program and the plans that are in place to address them.

Personnel: Lack of Fulltime Administrative Assistant

The Department of Chemistry & Biochemistry currently employs a ¾ time administrative assistant. This level of administrative support is inadequate and insufficient for the needs of the department. And it is below the standard expectations of other Andrews University STEM departments.

Table 30: Administrative Assistant FTEs for STEM departments from 2013 data.

Dept	Admins	FTE	Majors	Credits/FTE	Summer Classes?
Biology	1	9	134	347	No
Chemistry	0.75	6	43	420	Yes
Engineering Computer Science	1	8.25	84	159	No
Mathematics	1	6.5	31	461	Yes
Physics	1	5.25	31	327	Yes

The Department of Chemistry & Biochemistry has more majors than two STEM departments who have fulltime administrative assistants. The number of faculty in the department is similar to three other departments who have fulltime administrative assistants. The department has a higher ratio of credits to FTE faculty than all but one of the other STEM departments, all of which have fulltime administrative assistants. Our faculty work through the summer providing courses for May Express and for our majors (and those from other schools) and cognates for majors in other departments. Two other STEM departments do not provide summer courses, though they do have fulltime administrative assistants.

The Department of Chemistry & Biochemistry should be provided with a line in the departmental budget to fully fund adequate fulltime administrative assistance, in keeping with the expectation and practice demonstrated within the STEM division

Personnel: Lack of Dedicated Stockroom and Lab Management

Chemistry labs require a variety of equipment, supplies, chemicals, and solutions to be safely organized for each lab and location. Furthermore, the standards for managing hazardous chemicals have changed in the past 20 years and continue to change. For example, Material Safety Data Sheets (MSDS) are now changing into SDS (Safety Data Sheets). For decades, the MSDS has been the backbone of OSHA's Hazard Communication Standard (HCS). The HCS has been revised by OSHA to align with the Globally Harmonized System (GHS) of Classification and Labeling of Chemicals. This has resulted in substantial changes that went into effect in June 2015. These types of changes require all chemicals in our facilities to comply with the new GHS requirements. Faculty and staff have been doing an adequate job, but maintaining an OHSA and EPA compliant facility requires understanding of standards, codes, paperwork, organization, and implementation that is challenging. Many chemistry departments, including at sister SDA colleges (Oakwood, PUC, Southern, and maybe more) have found it wise to employ a lab manager to help organize the stockroom, prepare for large lab classes, and manage hazardous waste. Several other departments here at Andrews University have successfully employed lab managers to facilitate learning, organization, management, and student training.

In an otherwise encouraging approval review report from the ACS see Appendix A the CPT highlighted the absence of a stockroom manager as one of the key gaps in our program. Partner STEM departments at Andrews (Biology and Physics) have been able to successfully grow with the right such person.

A stockroom and lab manager would facilitate re-allocation of faculty resources to improve teaching, mentoring, researching, and writing papers. In theory, this should open up opportunities for faculty to have additional time to expand their research activities, which can lead to outside funding (grants). Many peer schools, including SDA colleges, have a dedicated stockroom manager. The qualifications for a lab manager need not be at the doctorate level; an individual with a bachelors or masters degree could fill the position. As society increasingly appreciates the nuances of managing chemical hazards, the job of managing chemical waste according to best practice, government requirements, and insurance regulations becomes increasingly complex. Such an individual would need to lead the department in that arena, could potentially teach non-major labs, train student teaching assistants, train student researchers, fix and maintain equipment, and assist in coordinating the labs of future summer sections of popular service classes: General Chemistry and Organic Chemistry.

Student Teaching Evaluations

- One class, Chemistry Seminar, frustrates students. We have a high-level plan to change how we deliver our learning objectives for this course.

Curriculum

- Low-enrollment upper-division (UD) classes. We plan to investigate the feasibility of offering some courses, Inorganic Chemistry and Physical Chemistry II on an every-other-year basis.
- Extensive sets of pre-requisite requirements for UD classes makes it hard to transfer in to a chemistry or biochemistry major. This is really a weakness of all chemistry and biochemistry programs beyond Andrews University, but a reality for us nonetheless. It makes it challenging to receive transfer students. It is possible for students to transfer into the program as sophomores, especially when they have already taken biology.

Equipment and Infrastructure

- Insufficient to no research lab space for each faculty: See **Table 31**.
    i. Chemistry research can involve setting up complex apparatus and equipment, while needing to have various supplies, glassware, and other equipment conveniently available.
    ii. Additionally, fume hood ventilation is needed for most research experiments.
    iii. It is not practical on a long term basis to share teaching lab space with long term research projects.
    iv. Teaching labs are shared among multiple classes and must be kept free of the chemicals and equipment that are available in research labs.

Table 31: Faculty research lab space

Ahlberg: has use of HH-316	Hayes: has use of PH-339 (shared with AuCS and biochemistry teaching lab)
Merga: Has no research space. Uses space in HH-215 (a teaching lab)	Murray: has use of HH-318. His large group of student researchers spills into HH-324, HH-325 (both teaching labs)
Nowack: Has no research space. Uses space in PH-339 (shared with AuCS and biochemistry teaching lab)	Randall: Has no research space. Uses space in HH-215 (a teaching lab) Also shares HH-316 (Ahlberg research lab)

- Lacking equipment: ultracentrifuge; cold room; MALDI-TOF; dynamic light scattering nanosizer; specialty microwave ovens for chemical synthesis; LC-MS system; LabView software. Additionally, service classes could benefit from modernization to digital data collection systems such as those above.
- Ongoing instrument expense (this may be a threat, rather than a weakness)
    i. NMR is approaching end of life
    ii. A new NMR console costs $300,000
    iii. Instruments have limited lifetime – all instruments need upkeep, consumables
    iv. Service plans would help maintain system life
    v. Functional but obsolete systems need to be replaced (Raman Systems 2001)

Financial: Chemistry and Biochemistry Departments Inherently Expensive

The following factors are attributes of chemical and biochemistry education US, and not a particular weakness of our department in particular.

- Time-intensive labs: a 3-4 hour hand-on practical learning opportunity (aka “lab”) takes 3-4 hours of faculty time, but generates only 1 credit. While the same 3 hours with students in a letters course will generate 3-4 credits.
- Expensive supplies that are cumbersome to manage: The lab fee charged to students is set by policy, rather than actual expenses. While we do not believe it is entirely out of line, it is not clear that the lab fee pays for the chemicals and disposable supplies. Further, to exercise good stewardship over our departmental budget, we pre-purchase our chemicals and supplies in a large order over the summer. We order for spring classes based on estimated enrollments the previous June. As one might anticipate, the estimates are not always perfect. Further, when students withdraw from a course, most often 10-14 days before the end of instruction for the semester, university policy is to charge the department for the lab fee despite the fact that all the supplies have been consumed, and faculty and student lab assistant labor has been expended.

Enrollment: Lack of Department-directed Scholarship Funds

- Chemistry and Biochemistry are mathematically and intellectually challenging majors that attract bright students.

- Through the 1990s, the department had established scholarships based on long-built relationships with alumni and departmental faculty. These scholarships were explicitly for our students and allocated by the department. These scholarships were an instrumental factor in recruiting committed students to our department. Conversion to the Andrews Partnership Scholarship (APS), severely limited the departmental-level recruiting value of these scholarships.

16. What opportunities are likely to present themselves to the program in the coming years, and what changes and resources are necessary to take advantage of them?

Create Opportunities with Internships and Coops

As will be noted in the following section, declining job opportunities for chemists and biochemists threaten the entire Chemistry and Biochemistry program here. The most effective response is to create relationships with employers that will find our well-trained graduates a compelling resource for their business. The resource necessary for forming and maintaining these relationships is human resources. These resources must include departmental resources and university resources. The university can follow the excellent examples of their benchmark schools such as Adelphi University (AU Center for Career and Professional Development), Anderson University (AU Career Development Center) and Ashland University (Career Services Center), to name only the first three schools in the 2012 Comparisons Institutions List, to create a robust internship and career transition center.

Increased Emphasis in Research for Graduate School Preparation

One metric that confirms the validity of an undergraduate learning experience is the presentation or publication of original research. Exploration of new ideas in a student's field of training requires the practical application of many of the concepts learned in classrooms and teaching labs. To accomplish the exploration successfully validates that learning. Within the Department of Chemistry & Biochemistry, changes that are needed to increase the number of active undergraduate researchers are: increased expectations of the majors; better mentoring opportunities by the faculty because of the work of a full-time laboratory manager to remove burdensome routine activities; better configured spaces within Halenz Hall to allow for research activities to occur without interruption by teaching activities.

Diversify Chemistry Careers by Collaborating with Business, Engineering and Computer Science Education

The traditional boundaries between the sciences, math and engineering are breaking down as the most productive innovations in today's sciences are occurring at the interfaces between the disciplines. An innovation in curriculum that would reflect this reality are the emergence of majors or concentrations that purposefully integrate the sciences, math, and engineering with business, computer science, and software engineering among others. The necessary resources to accomplish this are currently available. An important issue that must be addressed is the overpopulation of academic programs (majors) here at Andrews University. Accrediting agencies are concerned, that at Andrews there are too many programs for the population of students and faculty. Thus, the addition of interdisciplinary programs will require careful evaluation by the deans and the provost.

17. What threats may negatively impact the program in the coming years, and what changes and resources are necessary to mitigate them?

Declining Job Opportunities

As published in the spring 2016 American Chemical Society's Committee on Professional Training Newsletter, the president of the American Chemical Society, Donna Nelson, "has appointed a task force that is examining reasons for the disturbingly high unemployment rate of recent chemistry graduates." This high unemployment rate is the most worrisome threat facing the Department of Chemistry & Biochemistry at this time and in the near future. As you can see in **Figure 27** below the number of job openings in chemical sciences is on a downward trend. From anecdotal information from recent graduates, the struggle to find work is real.

One concrete response to this challenge is the creation of internships. See response to Question #16.

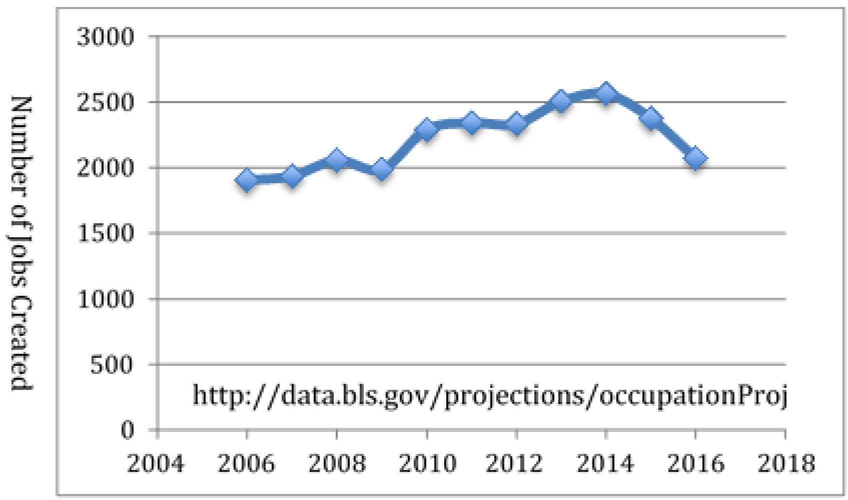

Figure 27: Number of Chemistry Jobs Created by Year

The projections for the future are not strong either. As highlighted in the **Table 32**, the total projections for employment from 2014 to 2024 for chemists and biochemists is about 43,000 job openings or 4,300 jobs per year. The United States alone is producing, in 11 years beginning in 2004, an average of 3160 chemistry and biochemistry doctoral graduates per year. That does not include any bachelor degrees granted in the US!

Table 32: Employment projections for 2014-2024

Occupation: Title	SOC Code	Employment (in thousands): 2014	Employment (in thousands): 2024	Employment change, 2014-2024: Number (in thousands)	Employment change, 2014-2024: Percent	Job openings due to growth and replacement needs, 2014-2024 (in thousands)	2015 median annual wage	Education, work experience, and training: Typical entry-level education	Work experience in a related occupation	Typical on-the-job training
chemist	Search									
Total, all occupations	00-0000	150,539.9	160,328.8	9,788.9	6.5	46,506.9	$36,200	-	-	-
Biochemists and biophysicists Show/hide Example Job Titles * Biochemist * Biological Chemist * Biophysicist * Clinical Biochemist * Physical Biochemist	19-1021	34.1	36.9	2.8	8.2	11.9	82,150	Doctoral or professional degree	None	None
Chemistry teachers, postsecondary Show/hide Example Job Titles * Chemistry Professor * Inorganic Chemistry Professor * Organic Chemistry Professor * Physical Chemistry Professor * Phytochemistry Professor	25-1052	26.6	30.7	4.1	15.4	8.8	75,060	Doctoral or professional degree	None	None
Chemists Show/hide Example Job Titles	19-2031	91.1	93.5	2.4	2.6	22.4	71,260	Bachelor's degree	None	None

http://data.bls.gov/projections/occupationProj

Declining Student Number Demographics

A trend that threatens many universities in the US is the declining pool of entering college students. This threat is increased by the additional resistance to religious, private university educational costs with its commensurate student loan burden. This trend directly affects the number of chemistry and biochemistry majors and the number of students taking chemistry and biochemistry classes which supports our department. Comparing the **Figure 28** and **Figure 29** also demonstrates that non-public high school graduates are declining and projected to decline through the 2020-21 school year, making recruiting a significant challenge. The department's best responses to these challenges are to seek an increase in student scholarships, to be a part of creating a compelling undergraduate university experience and, as mentioned before, to provide clear career assistance starting the first year a chemistry or biochemistry major is in attendance.

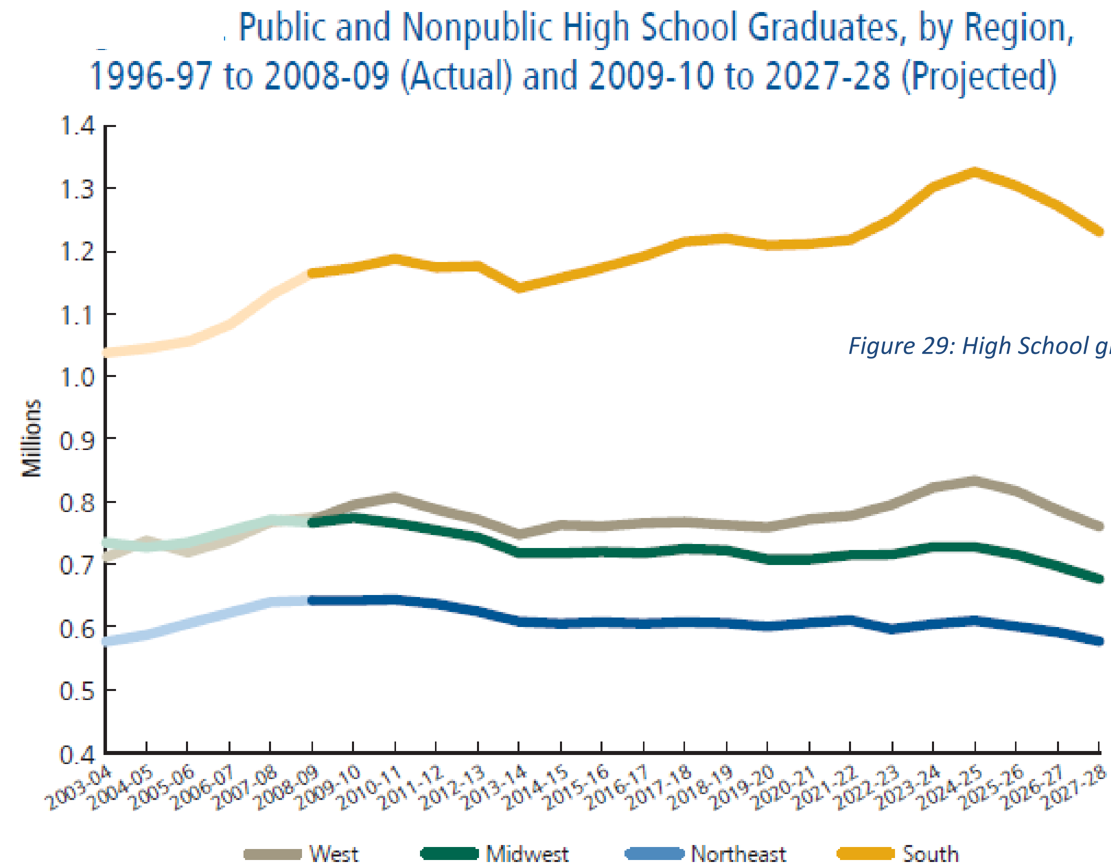

Figure 29: High School graduation rates by region

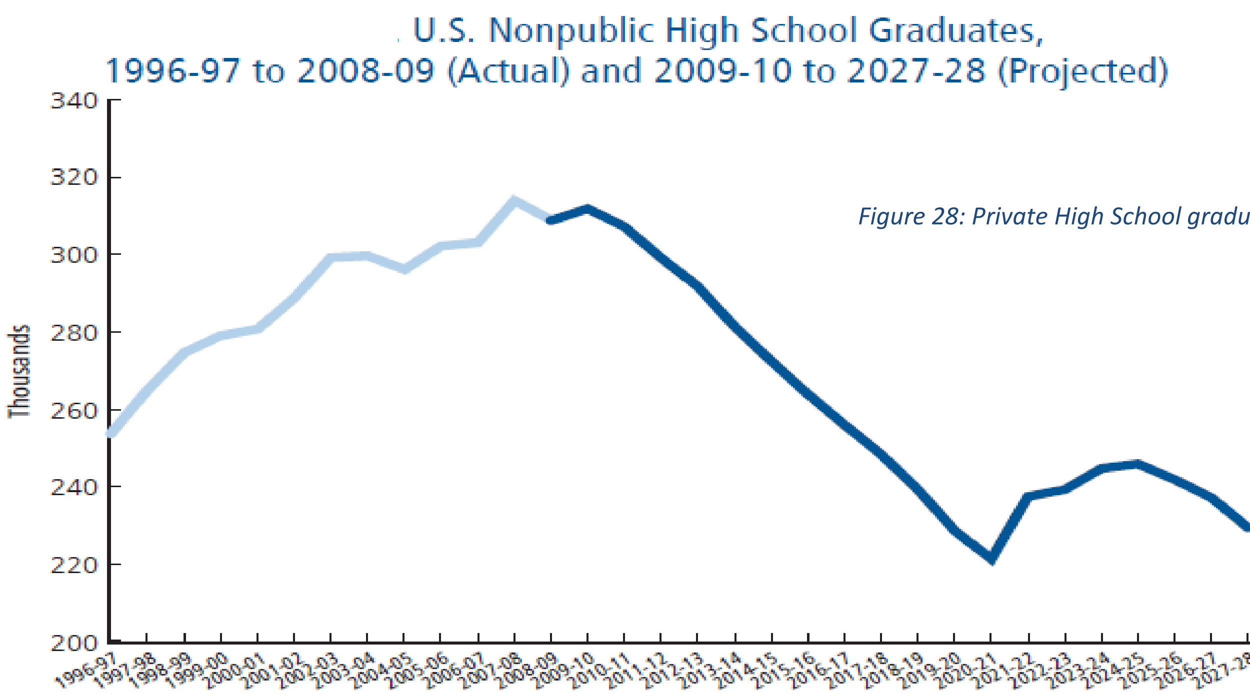

Figure 28: Private High School graduation rates

Declining Readiness of the Students

An on-going challenge that is a part of many science departments is the lack of readiness for college-level course work by a significant proportion of entering students. One measure of this lack of readiness is poor performance in mathematics preparation. For example, the percentage of Andrews applicants to the Department of Chemistry & Biochemistry that scored the lowest possible MPE (Math Placement Exam) equivalent on their ACT/SAT tests is shown in **Table 33**. A score of E0 demonstrates a nearly complete deficiency of college level algebra and arithmetic.

Table 33: Percent of students scoring at the lowest level of mathematics preparedness

Years	% of E0
2012-14	31.0
14-15	32.4
15-16	31.4

The impact of this lack of readiness is subtle but significant. Resources (time and talent) that are diverted to assist the under-prepared student can't be used to: better advise majors, mentor research nor serve the university. The responses to this challenge are limited. Recruiting prepared students is the primary solution.

18. What should be the future directions of your program and what steps and resources are necessary to take your program in that direction? How might changes and trends in technology, student demographics, and enrollment affect this direction?

Maintain ACS Approval

The benchmark that distinguishes this department from every other SDA Chemistry and Biochemistry department is the American Chemical Society approval. Since 1976, the University has created and maintained the necessary facilities, instrumentation, curriculum and faculty to meet their high standards. The administration and department must commit financial and human resources to continue ACS approval. The main threat to continuing ACS-approval is the lowering undergraduate enrollments. There are no ACS-approved schools with an undergraduate enrollment of less than 950.

Because of the very nature of chemistry and biochemistry, the technology of chemical instrumentation will be a constant challenge to maintain its relevance and its currency. The commitment of the administration to meet the challenge is vital. The department must continue to create and maintain strong ties to its alumni so that they will collaborate with the administration in that commitment.

In terms of technology of instruction, the vital exposure of chemists and biochemists to hands-on techniques of the instrumentation precludes almost all classes delivered on-line or distance education. So instructional technology is not a threat or opportunity.

The ACS Committee of Professional Training, the entity that provides the ACS approval process, voted to require a curriculum addition in the form of teaching and learning experiences about the chemistry sub discipline of macromolecules. Macromolecules include plastics and other polymers. The department has initiated changes in the curriculum that will satisfy the ACS approval requirement in a timely fashion

Enhance Quality Faculty

The department, through God's grace, has several outstanding faculty members. They provide the instruction, advising, research, and inspiration for our students. They are irreplaceable. The department and the university must: devise and implement new mechanisms or policies for rewarding outstanding faculty and for continually assessing faculty performance as scholars and teachers; foster an exciting intellectual environment by providing opportunities for more dialog and engagement with other faculty and peers in their field; develop ways to enable faculty to focus their time on being highly productive in their core academic activities (research, scholarship, and creativity; teaching; public engagement). (Adapted from Cornell University Strategic Plan 2010-15)

Two deficiencies stand in the way of fostering faculty development: a lack of time and space. In order to enable faculty to have enough time to engage in research and in the mentoring of undergraduate research, the need of a stockroom lab manager must be addressed. Furthermore, in order to enable faculty to have enough space to engage in research and in mentoring of undergraduate research, the lack of research space for individual faculty must be addressed. As mentioned before, three of the six faculty members have no dedicated research space. The lack of controlled spaces strongly hinders chemical research. A chemist cannot mix teaching lab space and research lab space. The research experiments are literally threatened by the curious and ill-prepared interest of students in teaching labs. While a chemical stockroom and lab manager will free up time for research, research space must be provided in the near term. Faculty engagement and satisfaction in their field demands it.

Increase Relevance of Curriculum

The undergraduate chemistry and biochemistry curriculum must prepare students to succeed in the field of chemistry that actually exists, not in the field the faculty were trained in decades ago or wish it to be. A relevant curriculum is maintained in the Department of Chemistry & Biochemistry in at least three ways: the American Chemical Society establishes curriculum guidelines for professional training, the faculty actively further their knowledge through research in their specialty and the faculty engage with their peers in chemical education by attending and presenting at chemical education conferences, especially, the Biennial Conference on Chemical Education.

The American Chemical Society's Committee on Professional Training (CPT) approves our chemistry and biochemistry degrees. The CPT's most recent guidelines requires all approved programs to train chemists in the sub-discipline of chemistry called polymer chemistry. The department is currently evaluating how it might fulfill this requirement. The curriculum changes should be in place in the next year. This change will require little to no financial or human resources to execute.

Increase Administrative Assistant Support

The inadequate administrative assistant support reduces the effectiveness of departmental responsibilities such as budgeting and recruitment as well as faculty, advisor and chair support. The department becomes stronger overall and the faculty can do their essential work better with a fulltime administrative assistant. It is an important goal for the department to increase the administrative assistant to full time.

Near-term Gaps to Close

Build Research Publication Capacity

Faculty research that mentors undergraduates and refreshes faculty knowledge in their discipline also helps maintain the relevance of the curriculum in the department. The primary limiting factor in our department that hinders faculty research is time. Our faculty are using their valuable time for routine chemistry department responsibilities such as stockroom organization, chemistry lab preparation, chemical inventory, supplies inventory, routine instrument maintenance, routine NMR cryogen management, gas cylinder management, hazardous material management, teaching assistance training, safety equipment inventory, safety training of students and teaching assistants and teaching assistant management. None of the above responsibilities require a doctoral degree. They can be managed with a Masters level chemist. The addition of a stockroom and laboratory manager would free up the faculty to do the things faculty do best: teach, advise, mentor.

Faculty engagement with their peers is strongly supported by the department and the Dean of the College of Arts and Sciences. In the past two Biennial Conferences on Chemical Education (BCCE), either all the faculty attended and/or presented (2014 in Michigan) or 50% attended and/or presented (2016 in Colorado). In both conferences, faculty returned with ideas that were immediately integrated into their classes. The Department must continue that level of engagement of faculty with their peers.

Appendix A

American Chemical Society

COMMITTEE ON PROFESSIONAL TRAINING
1155 Sixteenth Street, N.W.
Washington, DC 20036

Fax: (202) 872-6066
Email: cpt@acs.org
Web: www.acs.org/cpt

Cathy A. Nelson, *Secretary* (202) 872-4589

29 December 2015

Dr. D. David Nowack, Chair
Department of Chemistry and Biochemistry
Andrews University
Berrien Springs, MI 49104-0430

Dear Dr. Nowack:

The Committee on Professional Training reviewed your department's periodic report. Based on the information available, the Committee concluded that the chemistry program meets all of the requirements in the ACS Guidelines and agreed to **continue approval.**

The Committee commended the administration for supporting the significant renovation of Halenz Hall and the acquisition of new instrumentation. The Committee praised the very positive atmosphere for promoting undergraduate research among chemistry majors and the well-structured plan to develop student skills. The program self-evaluation plan appears to be very solid, and the diversity of the faculty is excellent. The Committee congratulated the department and Dr. Desmond Murray for receiving the 2012 Michigan College Teacher of the Year Award.

The Committee made the following suggestion for the continued development of the chemistry program.

Support staff. According to Item 3.4b of the periodic report form, the department does not have a stockroom manager. The Committee encourages you to discuss this staffing need with the administration to identify a mechanism to fund this important position.

The Committee made the following recommendation that requires action by the department.

- **Periodic report form.** At the time of the next review, the Committee asks that the chemistry courses used for certification be correctly classified in the curriculum tables. Section 5 of the ACS Guidelines provides the definitions for introductory, foundation, and in-depth course work.

As specified in section 5.12 on page 29 of the ACS Guidelines booklet, you must adequately address the above recommendation in the next periodic report package that you submit for review by CPT. Your program's next periodic report will be due in **2019**.

Please do not hesitate to contact me if you have any questions about the information in this letter or the expectations for ACS-approved programs.

Sincerely,

Cathy A. Nelson

Cathy A. Nelson
Secretary
Committee on Professional Training

CAN/dth/daa

c: Dr. Neils-Erik A. Andreasen, President