University of Maine System
Program Integration
Round Two

Physics

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

UMS Chief Academic Officers'
Summary and Recommendations

Physics

The Program Integration Physics team met and reviewed course offerings/programming within the UMS to discuss opportunities for curricular alignment, resource allocation and program management and explore collaborative models of course delivery in an effort to expand access to physics courses across the seven campuses. The team provided an overview of current physics curriculum/coursework available within the system recognizing the wide variations in physics offerings across campuses as factors impacting collaborative efforts in addition to other factors including faculty and instruction, instructional differentiation, workforce considerations and program difficulties. There was also particular emphasis on workforce challenges (faculty, funding, and research) and laboratory resources (facilities, equipment, and support). The Physics team felt opportunities for system wide growth to increase enrollment and expand access to physics courses on all campuses however recognized the need for additional faculty and support (including support courses) to bolster current offerings. While the Physics team felt online delivery was not conducive to physics instruction (laboratory requirements, specialized equipment needs, active peer engagement), the need to explore this further remains an important charge for this group.

Recommendations:

1. Align course numbers across campuses as appropriate to support transferability of courses and degree completion.
   (Projected timeframe: Spring 2017)
2. Support physics faculty in opportunities to continue to explore collaborative efforts at the campus, community, and system level via an annual faculty meeting/retreat.
   (Projected timeframe: Annual meeting – Spring 2017)
3. Support and strengthen existing programs for physics majors by exploring alternative course delivery models that could incorporate online/virtual instruction to further increase access to physics course offerings particularly in light of limited physics on a number of UMS campuses.
   (Projected Timeframe: Spring 2017)

Report and Recommendations of the Physics Program Integration Team

Executive Summary

We summarize our findings from the report into a single list of our major findings:

1. UMaine teaches nearly 10,000 Student Credit Hours (SCH), USM about 3,600 SCH, UMF about 500 SCH, and the other campuses combined teach about 575 SCH. Stated differently, UMaine teaches roughly 2/3 of all SCH in physics in the UMaine System.
2. Faculty numbers at the large campuses are shrinking. At UMaine they have gone from 16 to 12 research-active faculty since 2005. At USM they have gone from 4 to 2 (1.5 FTE) very recently.
3. There is only limited instruction in physics at the UMA/UMM/UMPI campuses, focused on only life science/pre-med majors, with instructors typically teaching out of field and not in close contact with colleagues at other campuses. There is no support for engineering students who may wish to transfer at a later time.
4. Differentiated instruction in the introductory courses is essential to ensure the success of students with different pathways ahead of them and to comply with accreditation (*e.g.*, ABET requirements for engineering students).
5. Coherent instruction across multiple sites requires clear, effective, ongoing communication to establish consistent teaching methods, course expectations, and measures of student outcomes.
6. For effective instruction to be aligned with research-based course improvements at UMaine requires professional development of all instructors.
7. Effective instruction requires hands-on learning and engaged students, be it through laboratories, studio courses like Physics by Inquiry (UMaine) or Workshop Physics (UMF) where all instruction is lab-based, or education research-based small group learning activities that use guided inquiry, as supported, for example, by the Physics Education Research Laboratory at UMaine. We do not recommend online instruction for physics in the UMaine System.
8. Funding has not kept up with teaching loads. Cost cutting efforts have drastically affected the ability of UMaine to respond to increased enrollments. USM is struggling with the consequences of retrenchment and retirement. UMaine, USM, and UMF all struggle to keep laboratory equipment updated to meet 21st-century needs.

The primary recommendations of our Team are:

1. To support and strengthen existing programs for physics majors, particularly at USM, which has been cut to a level that is not sustainable, and at UMaine, which is in danger of losing the value of its research-active status.
2. To carefully align course numbering across campuses in a way that preserves local structures, but only if course quality can be assured across all campuses.

3. To create an annual meeting of the UMaine System physics faculty which would include appropriate Community College instructors (though the Community College System was not included in this Program Integration process) and whose purpose would be to foster community, align instructional goals, and develop collaborations based on opportunities arising through changes in technology, all while keeping in place the role of campus faculty governance and the knowledge local faculty have of their own programs and students.

I. Introduction and overview

The Program Integration Team for Physics ("Physics Team") was made up of the following members: Michael C. Wittmann (UMaine, chair), David Batuski (UMaine), Frank Dudish (UMaine), Jerry LaSala (USM), Paul Stancioff (UMF), Chris Magri (UMF), and Bob Dixon (UMFK, until December). In addition, Carlos Luck (USM, engineering) and Dan Philbrick (University College) participated in early meetings.

The Physics Team met in person on the UMaine campus with all the other teams in October, 2015. We had a lengthy online conversation in early November, 2015, at which point we gathered information from the participating campuses (issues related to this task are provided in section III.D). Two non-UMaine members of the team, Jerry LaSala and Paul Stancioff, were invited to UMaine for its annual program review by an external advisory board, providing opportunities for substantive conversation about instruction in the UMaine System. Throughout this process, there were no representatives from the UMA, UMM, or UMPI campuses. As will be explained below, their physics instruction is different from that at UMF, USM, and UMaine. There is no physics instruction at UMFK, though Provost Dixon, a physicist, sought opportunities to bring physics to the campus.

The charge given to the Physics Team was to find ways of aligning instruction at our individual campuses to provide better opportunities for our students to successfully complete required physics courses. Though we had on our Team a member of last year's Engineering Program Integration Team (APRIP, at the time), we recognized that the need for program integration was not restricted to only engineering students. Thus, we considered instruction for all students in physics, while looking at the overall structure of our programs and the investments that would be needed to allow all System campuses to teach using effective and proven research-based instructional tools.

The value of physics comes not only from the majors in our programs (at UMaine and USM) but in the courses we teach for those outside our major. These fall into three groups: general education courses for students required to take a laboratory science course ("gen ed"), physics for the life sciences, forestry, and pre-med population ("life science/pre-med"), and physics for engineering students and physics majors ("engineering/majors"). At UMaine, there is a fourth sequence, for Engineering Technology students, similar to the life science/pre-med course but for a different demographic. The differences in the courses are primarily around the mathematics used in instruction – very little math in the gen ed courses, algebra and trigonometry in physics for the life sciences, and calculus in physics for engineers and majors. Even though there are multiple strands of introductory physics instruction, the canon of what is taught in physics is standard throughout the United States. For nearly all introductory courses, the scope and sequence are essentially the same, the style of instruction is the same, and the textbooks are essentially the same, suggesting great compatibility between courses at different institutions. But, as will be described below, based on our experiences in the classroom, we cannot recommend that courses be combined in ways that are detrimental to students, and we do not support sharing teaching across geographically distant campuses, given the low quality of online instruction in laboratory courses and the inability of online instruction to address student misconceptions using pedagogically appropriate tools. Because students at many of our campuses spend much of their time in group learning activities in either problem solving, laboratory work, or developing their conceptual understanding, online instruction is unable to provide the tools for effective teaching. Students need hands-on learning.

The primary recommendations of our Team are: (1) to support and strengthen existing programs for physics majors, particularly at USM, which has been cut to a level that is not sustainable, and at UMaine, which is in danger of losing its valuable research-active status, (2) carefully align course numbering across campuses in a way that preserves local structures, but only if course quality can be assured across all campuses, and (3) to create an annual meeting of the UMaine System physics faculty which would include appropriate Community College instructors (though the Community College System was not included in this Program Integration process) and whose purpose would be to foster community, align instructional goals, and develop collaborations based on opportunities arising through changes in technology, all while keeping in place the role of campus faculty governance and the knowledge local faculty have of their own programs and students.

II. Status of existing physics instruction in Maine

To understand our recommendations, we describe the way in which physics is taught at the campuses of the UMaine System and the lessons we have learned from how we teach. We move from largest to smallest and group together the three campuses where only 2 life sciences/pre-med physics courses are taught.

A. UMaine

Because UMaine has the most physics instruction, it is described in greater detail than the other campuses. This serves, in part, to illustrate how it is not easily possible to export the teaching model to other campuses.

1. Faculty and Instruction

The UMaine Department of Physics and Astronomy has 12 tenure stream faculty (down from 16 in 2005) and 3 full time instructors. There is also one adjunct, a senior research scientist who teaches one of the large lecture courses for engineering students. In 1997, the department taught roughly 6,200 Student Credit Hours (SCH). From 2005 to 2015, there was an increase from 8,100 to nearly 9,800 SCH (a 21% increase) (see Figure 1) at a time when the number of research-active, tenure stream graduate faculty fell from 16 to 12 (a 25% drop) and the total number of instructors dropped from 17 to 15 (a 13% decrease) (see Figure 2). The loss of especially graduate faculty has had a profound impact on our ability to offer a comprehensive graduate program and upper division physics courses. As is explained below, a strong graduate program is essential for the success of our undergraduate program.

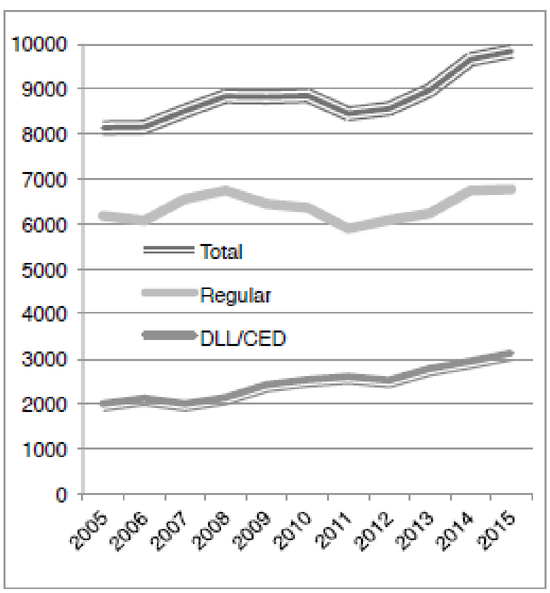

Figure 1. Student Credit Hours taught by year, split by funding source (regular or DLL).

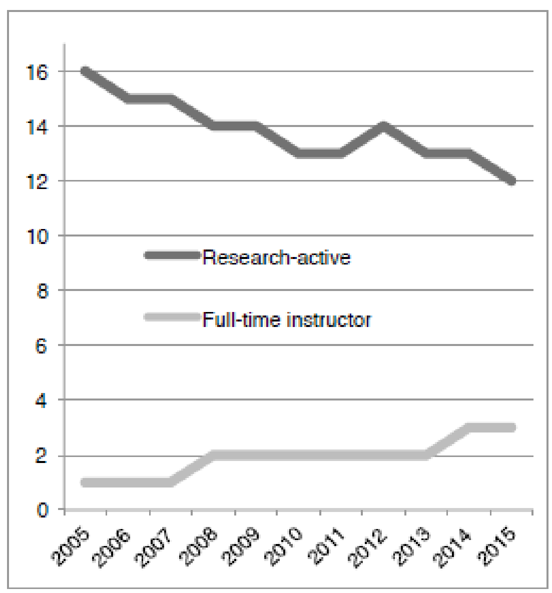

Figure 2. Number of faculty at UMaine.

2. Instructional differentiation

UMaine teaches a comprehensive physics sequence for general education classes and four populations of students: pre-service teachers, engineering technology students in the School of Engineering Technology (SET), life sciences and pre-med students, and engineering and physics majors. The gen ed course is a one semester laboratory physics course taught once a year that changes format and topic depending on the instructor. The pre-service teachers course uses Physics by Inquiry, a studio curriculum with 6 hours of hands on instruction per week, developed based on decades of research into student learning of physics, with special attention to topics taught in elementary school classrooms. There are two semesters of this course, though they can be taken in any order. The engineering technology, life sciences/pre-med, and engineering/majors courses all use the same format: 2 hours of lecture, 2 hours of laboratory, and 2 hours of problem solving and group learning activities per week (i.e., 4 of 6 hours of instruction are in focused, small group learning environments). For most students in other majors than physics, these courses are a 2 semester sequence. The life science/pre-med and the engineering/major courses are offered in the summer, as well.

Experience has shown that we cannot mix these groups of students into the same course without adversely affecting all populations. Pre-service teachers are taking a course that emphasizes teaching methods, not just physics content, and covers far fewer topics than other courses, as a result. SET students and engineering students are typically first year students, but with very different SAT scores and math skills. SET students and life sciences/pre-med students are using the same math skills, but the life science/pre-med students are typically juniors or seniors, no longer adjusting to the college experience, and better aware of how to succeed in a large course. If a combined course were taught, the pace of instruction would be too fast for some – they might struggle to keep up and either fail out or not actually learn the needed material. Such a course acts as a filter, rather than providing necessary skills for later success. If the pace is adjusted for those who struggle to keep up, the pace is too slow for some, and they do not acquire the pre-requisite skills needed in their majors. Thus, instruction is separated based on major, grade, and mathematical abilities.

Overall course enrollments continue to grow and are determined in large part by the admissions of majors in other programs. The life sciences/pre-med course has 160 students in its first semester and over 100 in the second (the change is due to some majors only requiring the first semester), while the SET course has 80-100. The engineering/majors course is taught both starting in the fall ("fall-start," with nearly 300 students in the first semester and 200 in the second) or starting in the spring ("spring-start," again with nearly 300 students in the first semester and 270 in the second). Course capacity for any given course is roughly 360 students, based on present limitations in departmental facilities and personnel (see below about workforce considerations).

The department also teaches Astronomy courses (as a gen ed course), with a single-semester general astronomy course that is taken by hundreds of students a year. There is an online version of the course, taught as an overload by a faculty member, that is dependent on his ability to teach the course.

The fall-start and spring-start engineering/major courses are required of different engineering majors in the College of Engineering, respectively, with some wishing for students to pass their first calculus course before taking physics and others suggesting that students take calculus and physics in parallel. For both the fall- and spring-start courses, multiple lectures must be held to accommodate all students, because there is no lecture hall large enough to hold all students at once. Because instruction of the fall- and spring-start courses is provided by two different instructors, the department has experience with aligning instruction in two different courses.

3. Workforce considerations

The faculty of UMaine are internationally recognized for their work in condensed matter physics (in particular surface science), optics, biophysics, astronomy, nuclear physics, and education research. The faculty publish between 20 and 30 articles, book chapters, or other publications per year and present between 40 and 100 talks and posters per year. Since 2007, the department has averaged $2M/year in external funding, with a slight increase every year (see Figure 3). Awards and recognitions of faculty in the past decade include a UMaine System Trustee Professorship, the Humboldt Prize, the Foresight Institute Feynman Prize (for advances in the theory of nanotechnology), Fellow of the American Physical Society (for excellent in physics education research), and being named in the description of the Nobel Prize for Chemistry in 2014 (for the independent invention of sub-wavelength microscopy). Because not all faculty appointments are identical, there are approximately 5.5 equivalent full-time researchers among the 12 research-active faculty. For each full-time researcher (e.g., averaging scholarly production over 5.5 people), in the past 3 years the department averages 3¼ publications, 9½ talks, roughly 2 new grants bringing in roughly $450k each year, and 6 graduate students. This is a highly productive department – at a recent meeting of the New England chairs of physics departments at land grant institutions (an annual meeting attended by the chairs of UMaine, UNH, UMass-Amherst, URI, UVM, and UConn), the chairs were astonished at the productivity, given the very high student credit hours (SCH) provided by the department.

Figure 3. External funding secured by Department since 2007, averaging $2M/year.
(* funds for FY 2016 are for only the first half of the year.)

As noted above, most instruction in the large service courses happens outside of lecture (with only 2 hours of lecture time, 4 hours of small group activities). Instruction in recitations and labs is led by graduate students from the Department of Physics and Astronomy, and from other departments if needed. The department most recently taught over 80 labs and recitations in the fall semester and over 70 in this spring semester. Support for this instruction comes from 15 Teaching Assistantships funded by the Graduate School for 45 of these sections and ad hoc funds (see below) for the rest. Based on room limitations, lab sections are limited to 24 students at a time (thus, a course with 288 students requires 12 lab sections if schedules are arranged to fill every section perfectly) while recitation sections are 24 or 30 students, depending on the course (and the same 288 person course requires 12 or 10 sections of recitation, respectively). The 30 person sections are in courses emphasizing group learning activities to develop conceptual understanding of the physics, not just mathematical problem solving, and have both teaching assistants and undergraduate co-instructors called Maine Learning Assistants (MLA). The MLA program began as an NSF-funded modification of instruction and is transitioning to other funding sources, in part from CLAS funds and the department unified fees.

The MLA program is but one example of many initiatives undertaken based on physics education research, the study of the teaching and learning of physics. The UMaine Department of Physics and Astronomy is home to the internationally known Physics Education Research Laboratory. Research to develop more effective courses and evaluation of those courses has guided curricular modifications to the gen ed, pre-service teacher, introductory engineering/majors course, introductory life sciences/pre-med course, and many, many upper division courses. Few departments in the country can report such wide-ranging use of physics education research to guide the development of reformed, research-based teaching of courses throughout the curriculum. Implementation of such curricular reforms requires substantial professional development for the graduate students and faculty who are teaching. Efforts to expand research-based teaching to departments in other campuses would require similar engagement and professional development.

4. Program difficulties

In a time of shrinking faculty and static support for teaching assistantships, the increase in SCH taught by the department has led to substantial difficulties in productivity and teaching.

First, the faculty profile is changing. The faculty are changing from a primarily research-active faculty (1 of 17 in 2005 were full time instructors) to an increasingly teaching-active faculty (3 of 15 in 2015 and possibly 4 of 16 in 2016, see below). There have been no new hires of tenure-stream, research-active graduate faculty since 2010. That search was contingent on funding from the National Science Foundation. The last search approved for the department was in 2007. Hiring non-research faculty will likely soon drastically affect the department's research productivity and ability to secure external funds. This ability is in jeopardy as competition for funding becomes more difficult, and faculty must spend an ever greater time on securing funds to support their labs and students. High quality research also plays an important role in the undergraduate classroom by (1) providing spaces for student senior capstone research projects and (2) bringing cutting edge research into the classroom, motivating students and showing how what they learn is playing an active role in contemporary physics.

Second, funding for instruction has not kept up with teaching. The department has had to rely on more ad hoc funding for its laboratory and recitation teaching. The number of teaching assistantships has not changed since the late 90's, when the department was teaching fewer than 7,000 SCH. The existing assistantships cover 45 sections of instruction, and securing funds for the remaining 25 to 40 sections, depending on the semester and with increased growth projected in the future, has relied on DLL/CED funding, section funding from the College of Liberal Arts and Sciences, or use the departmental operating budget or unified fees distribution. Preparing graduate students for the teaching they are doing requires an investment of resources in preparing students for an unfamiliar task. The department includes this as part of its professional development of graduate students for future positions in academia and industry. Though the department is presently searching for 2 full time instructors to teach up to 12 sections of labs, this will not address the structural shortfall adequately, meaning that ad hoc funds will continue to be needed in the future. There are substantial transactional costs involved in ad hoc funding, beyond the need to secure the funding itself.

Third, the department's facilities are outdated. Wear and tear on equipment, with hundreds of students in lab per semester, is substantial. Because the department picks up substantial costs related to ad hoc funding of graduate student instructors, it has been slow to upgrade its laboratory equipment. Recent efforts have allowed the department to start improving facilties and upgrade equipment, but it is a slow and expensive process at a time of budget cuts.

5. Implications for the UMaine System

The experiences of UMaine are important for the entire UMaine System. When teaching physics as a service course for other majors, different students require different kinds of instruction, depending on their mathematical background, class, and major. Differentiated instruction is essential to ensure the success of all the students coming through our departments. This requires substantial professional development for those courses in which lecture, laboratory, problem solving, and group conceptual learning activities are distinct activities that need to be blended together to make a complete course. Students transferring to UMaine from other campuses would be expected to have had a similar experience to succeed in later courses.

The problems we observe are equally important. First, good instruction requires invested faculty with high levels of expertise. UMaine has excellent research-active faculty who are deeply invested in teaching, and the department's instructors are full-time physics instructors, meaning their sole professional focus is on their teaching. To teach using methods based on education research requires dedication and investment. Building coherent instruction out of disparate instructional methods (lecture, lab, etc.) requires planning and focus. Finally, keeping laboratory equipment up to date requires investment, and the laboratories for different courses (and the different majors taking them) may look very different. These results affect our recommendations for the Program Integration process, as described below.

B. USM

Physics instruction at USM is second only to UMaine, but the profile of the department, the solutions it has found to structural limitations, and the needs of the department are very different.

1. Faculty and Instruction

The USM Department of Physics currently has 1.5 FTE faculty, since one of the two tenured faculty has a half-time appointment as Planetarium Director, down from 4 faculty in 2013 due to one retirement and one retrenchment (since ruled improper by binding arbitration). In addition, the department employs several adjunct instructors (three in spring 2016) and uses upper-level undergraduate Learning Assistants to supervise introductory laboratories. In 1997, the department delivered a total of 2250 SCH; in 2005, the total was 3184, and in 2015, 3570 SCH. This represents an increase of 59% in SCH while the number of tenure-line faculty decreased by 50%.

2. Instructional differentiation

USM offers three strands of introductory physics instruction, roughly parallel to the offerings at UMaine. Notably, lab courses are listed separately from lecture courses, but students are expected to take these in conjunction with each other. (See below on considerations concerning aligning course numbering.)

For general education, sports medicine, technology and other majors, a gen ed course is offered every semester and every summer. For life science/pre med students there is a separate two-semester algebra and trigonometry based sequence that is offered starting in the fall and again in the summer every year. For physics, chemistry, and engineering majors, the department teaches a calculus-based sequence starting in the fall, again repeated in the summers. The life science/pre-med and engineering/major courses share the same laboratories. This is not considered ideal but is a product of resource constraints in terms of both personnel and space. It is one reason that separate lab courses are required, independent of the lecture courses, allowing students from different courses to take the same lab.

In addition the department offers an introductory general astronomy course with a separate but associated lab, which also serves a large general education population and is offered every semester and summer.

3. Workforce considerations and program difficulties

The program is at present in crisis. Even with Learning Assistants to help in laboratories and adjuncts to support some instruction, having only 1.5 FTE faculty is too little to support a full program. A failure to replace a retirement at a critical time, in addition to the retrenchment of faculty, have created a nearly unsustainable program.

C. UMF

Though UMF does not have a physics major, it has the most stable, sustained, and large program outside of UMaine and USM.

1. Faculty and Instruction

Physics at UMF is part of the Division of Natural Sciences. The faculty is comprised of two tenured full time faculty and one part-time adjunct faculty member. There is not a physics major on the books at UMF, although occasionally a student will design an individualized major (*e.g.*, "physics and mathematics") that includes upper-division courses taught as directed or independent studies in physics. Although the two tenured faculty members engage in other activities -- one focuses on physics education research and on public energy/sustainability education, the other on astronomical research involving radar and infrared studies of asteroids -- teaching is their primary focus, as is the expectation at UMF.

2. Instructional differentiation

The course profile at UMF is very different from the courses taught at UMaine and USM, consistent with the nature of the institution and its students.

The adjunct faculty member teaches two courses per year within the division: one section of Introductory Meteorology each semester, aimed at general education students but also at elementary and secondary science education majors. The two tenured faculty teach primarily courses at the introductory or intermediate level. The introductory-level courses are: Descriptive Astronomy, taught as a general education course but also included in the secondary education science major; Elementary Physics, a course directed at non-science students with an emphasis on the principles of physics and their application to topics in research and current issues in science; Musical Acoustics, an algebra-based course designed both for general education and for students in our music programs; Energy, Physics, and the Environment, an algebra-based course focusing on the physics of energy, directed primarily at environmental science, biology and geology majors; and General Physics I and II, a two-semester sequence that employs the laboratory-based “Workshop Physics” method designed by physics education researchers at Dickinson College. The General Physics sequence covers some but not all of the traditional topic areas that a physics or engineering major would take. Students in General Physics are typically majors in biology, secondary education science, math, environmental science, and geology. Among these majors are also a number of pre-professionals looking to apply to programs in medicine, dentistry, optometry, and other health-related professional schools. Thus, while the population is much like the life science/pre-med students at other campuses, the course is very different from that taught at other campuses for those students.

All of the introductory courses include a laboratory. As at the other campuses, labs are an essential part of the process of conveying to students the methods and philosophy of the scientific process, as well as emphasizing the distinct way that physicists think about the world. Furthermore, learning physics is not just a matter of learning correct ideas but also involves un-learning deeply rooted preexisting misconceptions, a process best carried out by having students collect data and then discuss the results with peers and an experienced instructor. Based on research in physics education, there is no legitimate substitute for an actual hands-on laboratory experience.

In addition to the courses in physics, the two tenured faculty also teach a section of First Year Seminar on a periodic basis. This course, required of all first-year UMF students, emphasizes reading, writing, and discussion skills as much as content. Topics have included astrobiology, the philosophy of time, archaeoastronomy (the role of astronomy in non-Western cultures), and physics in the arts.
For the most part the courses listed above are nearly fully populated. UMF classes are typically small with a strong emphasis on personal interaction and connection with the faculty.

As mentioned above in the description of the UMaine program, instructional differentiation is a key element in the value of our courses. The courses are directed at different audiences based on several factors. Preparation of the students, particularly with regard to their mathematics preparation, is one such factor, while their major is another. A biology major may choose to take Energy, Physics, and the Environment perhaps because of a weaker math background. But if she is in a pre-professional program she will need to take calculus as well as General Physics I and II.

3. Workforce considerations and program difficulties

Addressing the needs of these diverse audiences, with only a small physics faculty available to offer courses, is a major instructional challenge at UMF. For example, Elementary Physics -- the largest general education physics course, with two lab sections per semester -- has been taught in two versions during the past decade: "Einstein's Physics" covers relativity and quantum mechanics; while "The Physics of Cars" looks at traditional vehicles, alternative vehicles, and alternative energy generation. These two conceptual themes work well for a liberal arts audience, with the latter theme designed to produce informed citizens and consumers and the former theme stressing the philosophical conundrums associated with modern physics. Future teachers, on the other hand, might be better served by a course whose content is more concrete, content they could carry over to their own future classrooms. But such a course cannot be taught without reducing the frequency of some *other* course needed by education majors, such as Introductory Meteorology or Descriptive Astronomy. This is a significant concern given the traditional prominence of UMF's education programs.

The other major challenge is, unsurprisingly, the need to update equipment. This need is pronounced in the several general education courses, which in the past have been given a low spending priority so as to focus always-limited division funds on courses populated by science majors. Such a policy cannot be maintained forever, and indeed the equipment is now old enough that significant investments will have to be made over a prolonged period.

In summary, physics at UMF focuses primarily on a range of introductory offerings for general education students, future teachers, and future scientists, with a secondary emphasis on intermediate-level courses, first-year writing seminars, and the occasional upper-division course for students who wish to study physics intensively at a small campus. The personnel reductions experienced at UMaine and USM have not yet materialized at UMF, where the physics faculty has remained constant for two decades; but there are instructional challenges stemming from a small faculty with a limited budget teaching a diverse set of introductory courses. One low-cost approach to addressing these challenges would be to increase contact between the physics instructors on the various campuses, so that the UMF faculty could learn about, adapt, and implement fruitful ideas formulated elsewhere in the system. Our recommendations for the Program Integration process (described below) include a provision that would stimulate exactly this sort of cross-pollination.

D. UMA/UMM/UMPI

Where there is extensive physics instruction at UMaine, USM, and UMF, there is very little at UMA, UMM, and UMPI. As a result, we group these institutions together, because the profile of their course offerings is so similar.

In each institution, only 2 physics courses are taught: the two semester sequence of classes for life science/pre-med students. The average total enrollment per semester across all three campuses totals 70 students, with enrollments ranging from about 10 per course (at UMPI) to nearly 40 (at UMA). This comes to roughly 575 SCH across three campuses per academic year, only slightly more than half the SCH of the equivalent course taught at UMaine (which averages 130 students/semester).

We were unable to gather any information about laboratory facilities, but expect that labs are maintained well enough to support effective instruction for small student populations.

The life science/pre-med courses are not suited for students in engineering or physics, since the content is usually taught in a way that does not adequately prepare the student for future courses. ABET accreditation requires that students take the calculus-based course for engineers and majors, meaning that transfer students must re-take their physics course, though waivers have been given in the past for students with high enough grades in both their physics and mathematics (calculus) courses.

The instructors of the UMA/UMM/UMPI physics courses are regularly in flux, meaning there is little to no institutional history in teaching the material. From the information that we could gather, the instructors have rarely had a background in physics, often being chemists or mathematicians teaching out of field, or high school teachers asked to teach at the college level. Though such instructors are expected to be dedicated to the learning of their students, such instruction rarely comes with the insight of an expert, meaning that students may learn the details that are in a textbook, but not the nuances that come from advanced expertise in a field.

In the past, there were attempts at alignment of instruction across at least a few campuses. In the early 2000’s, efforts were made to align instruction at UMM with the equivalent UMaine course. But, the instructor for this course at UMaine was hired in 2008 and cannot recall ever having had a discussion of course content, instructional format, or expected outcomes with a UMM colleague. There has been no conversation between UMA and UMPI and UMaine about course expectations. In sum, the 3 courses taught at these 3 schools are isolated from other physics teaching within the UMaine System. Instructors at these campuses are not in touch with any other physics faculty in the UMaine System. This isolation is perhaps the most serious problem with instruction at these schools.

Taken as a whole, instruction at UMA/UMM/UMPI occurs in small classes with rarely more than 2 sections of lab and sometimes fewer than half (using the UMaine measure of 24 person labs). Content is focused on only one population, the life science/pre-med major. Instructors are typically teaching out of field and are not in close contact with colleagues at other campuses. There is no support for engineering students who may wish to transfer at a later time. We address these issues below, in our recommendations.

E. UMFK

At present, there is no regular instruction in physics at UMFK.

F. Other efforts: Bridge Year

Most of the emphasis above has been on the life sciences/pre-med students and the engineering/major students. Physics departments also provide a substantial number of gen ed classes for students needing to take a laboratory science course.

The UMaine campus has been involved in Bridge Year for two years, letting students in high school take the equivalent of the one-semester UMaine gen ed physics course over the full academic year. To ensure the success of these efforts, one member of the UMaine faculty devotes substantial efforts in working with each individual instructor in multiple ways. First, there is a collaboration on what is being taught, so that all courses cover roughly the same material. Second, the UMaine faculty member visits each of the Bridge Year classrooms at least once a year, but visits more often if the teaching is not aligned with expectations and needs improvement. This constrains Bridge Year efforts to schools that can be visited easily in one day (by a faculty member who has substantial teaching responsibilities and cannot spend the whole day in a car for a 1 hour visit – online observation does not provide a detailed enough picture of classroom implementation of the course). Third, it requires substantial infrastructure to ensure that Physics courses can succeed within the entire Bridge Year program.

The experience with Bridge Year as guided by the UMaine Department of Physics and Astronomy has shown that successful local hands-on instruction across multiple sites requires intense and regular communication. We can imagine a version of this process being used for physics courses in the life sciences/pre-med courses which already exist at UMA/UMM/UMPI, but that is presently lacking. Such a program would require further communication and interaction between the instructors at these campuses and the UMaine campus. Including USM and UMF in the conversation would be an obvious extension of such conversations. We could also imagine a similar process for the engineering/major courses, which do not yet exist at the UMA/UMM/UMPI campuses. We provide more details on our proposal for program integration, below.

G. Summary

The bulk of physics instruction in the UMaine System occurs at the University of Maine (ca. 9,800 SCH), followed by USM (ca. 3,600 SCH), UMF (ca. 500 SCH) and the smaller campuses (570 SCH total across 3 campuses). Most of the faculty in the System are located at UMaine, as well, with 17, followed by 2 at USM, 2 at UMF, and instructors at UMA, UMM, and UMPI. There are also adjuncts teaching at UMaine, USM, and UMF, equivalent to the instructors at UMA/UMM/UMPI.

In terms of cost, the physics courses at the smaller campuses require a large amount of overhead (e.g., lab materials and facilities) for a small population, without the benefits of scale that come at the larger campuses (UMaine, USM, and UMF). At the larger campuses, though, there are greater costs due to wear and tear from heavy use.

Lessons learned at UMaine and USM indicate that:

1. Differentiated instruction in the introductory courses is essential to ensure the success of students with different pathways ahead of them and to comply with accreditation (*e.g.*, ABET requirements for engineering students)
2. Coherent instruction across multiple sites requires clear, effective, ongoing communication to establish consistent teaching methods, course expectations, and measures of student outcomes.
3. For effective instruction to be aligned with research-based course improvements at UMaine requires professional development of all instructors.
4. Effective instruction requires hands-on learning and engaged students, be it through laboratories, studio courses like Physics by Inquiry (UMaine) or Workshop Physics (UMF) where all instruction is lab-based, or education research-based small group learning activities that use guided inquiry, as supported, for example, by the Physics Education Research Laboratory at UMaine.
5. Funding has not kept up with teaching loads. Cost cutting efforts have drastically affected the ability of UMaine to respond to increased enrollments. USM is struggling with the consequences of retrenchment and retirement. UMaine, USM, and UMF all struggle to keep laboratory equipment updated to meet 21st-century needs

III. Responses and Recommendations

The charge given at the beginning of the Program Integration process asked members of each Team to find ways to provide more equitable instruction across all campuses while also suggesting that such changes could, perhaps, lead to cost savings. Having summarized the nature of physics instruction at all the campuses, above, we now respond to suggestions that we were asked to consider and make our recommendations for how to address the charge.

A. Opportunities for growth

First, we look at the good news. Across the UMaine System, we see opportunities for growth at all our campuses. There is no physics instruction at UMFK, and instruction at UMA, UMM, and UMPI is quite limited. We are in favor of increasing enrollments at these campuses while ensuring the high standard of instruction required of these students if and when they wish to transfer to one of the other campuses to complete their degree programs. We assume that the existing laboratory facilities at UMA, UMM, and UMPI would support engineering/majors courses in addition to the life science/pre-med courses already being taught at each institution.

We also see the need for improved physics instruction at USM. At present, only 1.5 FTE faculty are supporting an entire program. This is simply too low, and it will affect the quality of all physics instruction for physics majors and introductory service courses for other majors. We firmly recommend the hiring of new faculty at USM to sustain the existing program and do not support improving physics instruction at UMA, UMM, or UMPI without first strengthening physics instruction at USM.

If we increase enrollment in physics at all campuses, and more students transfer to UMaine, which has the most comprehensive physics program in the UMaine System, we expect to see an increase in enrollment in upper division courses. This increase will be accompanied by a need for more options and electives for students to take, as they pursue different professional goals within their major. There will also be a greater number of students doing capstone research projects. UMaine will therefore also require an investment in highly qualified research-active faculty, moving away from the instructor hires to strengthen the graduate program and major, as well. This would provide more opportunities for senior capstone research, as well.

Given the turnover in instructors at UMA, UMM, and UMPI, we are hesitant to recommend the creation of engineering/majors courses (for students who might later transfer to UMaine or USM) until the quality of instruction can be assured. If a single instructor at each campus could teach both a life science/pre-med course and an engineering/majors course, and were in close alignment with UMaine and USM faculty (using mechanisms described below), we believe that this would provide a useful pathway to students who wish to graduate with degrees in engineering or physics.

Such growth in engineering/majors physics courses would require high quality calculus instruction at all campuses as well. We would expect any transfer students to have a firm grounding in the prerequisite courses and skills (such as writing) to ensure their success upon entering UMaine or USM.

We only recommend growth in the engineering/majors physics course if this prerequisite instruction is strengthened and there are clear indications that enrollments would merit the investment. Otherwise, the Physics Team supports strengthening the USM and UMaine programs and ensuring the ongoing sustainability of the UMF program. We refer to the experience with the Brunswick campus, which involved a novel but unproven approach to teaching physics and mathematics but had low enrollments and was closed recently, though we are unsure what conclusions to draw from it.

B. Recommendation against lab-centered online instruction

The Physics Team does not support online physics instruction. The Team recognizes that the UMaine System wishes to invest in online instruction for many of its majors, allowing for greater flexibility in student enrollment. We do not believe that such instruction is at present possible for a laboratory-driven course like introductory physics. Specialized equipment is necessary for teaching, especially when we are trying to find coherence among many different institutions. At the moment, there are no effective online laboratories that truly engage students with the concepts and the laboratory design and troubleshooting skills which are such an important element of the laboratory experience.

Further, an essential element of effective learning is the engagement with peers around ideas that all are learning. Extensive research has shown the value of interactive engagement in the introductory sequence, and results from the UMaine Physics Education Research Laboratory have shown the value in upper division classes, as well. These results hold for both laboratory instruction and for small group conceptual learning activities. To ignore the results of one of the top physics education research groups in the country, as well as the extensive literature on learning in physics, would be counter-productive.

Finally, online instruction is not presently of a form that helps students confront their common-sense but imprecise models of the world – their misconceptions are often strong and do not change with instruction unless adequately addressed. Research shows that this requires hands-on learning.

In sum, the Physics Team feels strongly that the value of physics education is best found through in-person instruction, making use of the value of interactive engagement, emphasizing the increased learning that occurs in such a setting.

C. Qualified recommendation to use identical course numbers

At the moment, multiple courses in the UMaine System have nominally the same content and student population, but the courses are not numbered identically. This creates confusion for students, such as when PHY 101 at USM means something different from PHY 101 at UMaine or UMF. At the same time, UMM agreed long ago to name its life sciences/pre-med course the same as UMaine's, with the desire to teach the same content in the same fashion, and UMaine and UMM share that course numbering with USM (but not quite, due to separate lab courses at USM). This inconsistency is maddening when comparing instruction across campuses.

The argument against aligning course numbering is simple. A course that is well taught and responsive to student needs at its local institution will, by dint of the differences between our campuses, be different from a course taught well and responsively at another institution. Though there might be strong alignment in course goals, the courses may end up being very different. Someone passing the course at one institution may not be prepared for the courses at another institution that require it as a prerequisite, as a result. Thus, using identical course numbering should only happen if the standards and outcomes are set to meet the goals of the most rigorous programs in the system.

We suggest that courses be renumbered System-wide for those courses for which it is appropriate, *provided that* there is a mechanism for ensuring equivalent standards of learning across all courses. Our recommendation is based on the UMaine experience with the engineering/majors courses (fall-start and spring-start sequences), as well as the UMaine experience with the Bridge Year program. In the former, conversation between faculty leads to appropriate alignment. In the latter, guidance by a central instructor leads to appropriate alignment. The Physics Team's suggestion for aligning courses is given below, namely through the use of annual meetings of instructors (and the ensuing openness to having further conversations at other times of the year).

A suggested course alignment is provided in the table below, where we use the UMaine numbering because of the dominance of the program in terms of enrollment and size. Actual alignment of these courses would not be trivial – the Course Equivalency table provided to the Physics Team had several errors in it that were inconsistent with the actual course content of the physics courses, in some cases, and ignored the need for differentiation (and the requirements of accreditation) in others. For example, the UMPI PHY 153/154 sequence is most closely aligned with PHY 111/112 at UMaine and USM, but is shown with a course equivalency of UMaine's PHY 102, 107, 111, 121 (for PHY 153) and PHY 105 and 112 (for PHY 154). We find this to be wholly inappropriate. UMaine's 102 is for pre-service teachers, 107 for School of Engineering Technology, 111 for life science/pre-med, and 121 for engineering and physics majors – we do not believe that the course *can* teach to all these populations effectively, all at once, and wish for course transfer to be only for the course it most resembles, instead.

Thus, one major reason to align courses would be to have better clarity about which courses actually align and which do not.

Course	**UMaine**	**USM**	**UMF**	**UMA**	**UMM**	**UMPI**
Gen Ed	PHY 105	PHY 101 & 102	PHY 110			
Life science/Pre-med 1	PHY 111	PHY 111 & 114	PHY 141	PHY 115	PHY 111	PHY 153
Life science/Pre-med 2	PHY 112	PHY 112 & 116	PHY 142	PHY 116	PHY 112	PHY 154
Engineering/major 1	PHY 121	PHY 121 & 114				
Engineering/major 2	PHY 122	PHY 123 & 116				

We note that certain strands of teaching, such as the pre-service teacher courses and the courses for engineering technology students, are not listed on this table. Further, it could be that the PHY 107/108 courses at UMaine are equivalent to the PHY 111/112-type courses at the other campuses (since the level of mathematics is similar), but it could be that they are different (because the students are not). Further examples include the unique physics courses taught at UMF, which have no equivalent elsewhere, at the moment.

Working out course equivalency requires careful discussion among the faculty at the different institutions. This is time consuming work, at a time when all our faculty are stretched by their other responsibilities. It is not a task to be undertaken lightly.

A major issue with this course alignment lies in the way that USM and UMaine treat their laboratory instruction differently. For all campuses but USM, laboratory instruction is included in the course (both in terms of registration and credit counts). For USM, a separate laboratory course is taken. As noted above, this is due to the lack of resources to teach separate lab courses for the life science/pre-med and the engineering/majors courses. The result is that credit counts for the same courses are higher at USM than at UMaine. This is an issue that would need to be resolved carefully, since the local definitions in individual departments must be respected unless affected by extraordinary circumstances.

We are hesitant in our recommendation for course alignment. The only reason to engage in it, it seems to the Physics Team, is to assist those few students who transfer from one institution to the next. The existing course equivalencies show that transfers are being interpreted too broadly (for example, the overly broad interpretation of UMPI PHY 153/154). Course renumbering would address these concerns and provide uniformity throughout the UMaine System. But, the corresponding difficulties are large. First, there is the matter of whether the courses are truly equivalent, how that gets determined, who determines it, and how we ensure ongoing alignment between the courses. We return to this point, below. Second is the matter of different course credits at different institutions, affecting resource allocation away from historical levels. Third is the matter of confusion for students where changes to course numbering are to be made.

We note, in closing, that we have emphasized Physics in our discussion of course alignment. The Physics Team had limited conversations about astronomy instruction, where other opportunities for alignment exist. UMaine’s AST 109 (and 110 lab) is perhaps equivalent to AST 100 (and the 103 lab) at USM and PHY 101 at UMF. No other campuses offer astronomy instruction. But, the Physics Team definitely sees opportunities for clarity when PHY 101 at UMF is a general astronomy course, PHY 101 at USM is a gen ed physics course, and PHY 101 at UMaine is a pre-service teachers course!

D. Expand Bridge Year

Given the need for Bridge Year classes to have local oversight in order to ensure uniformity of instruction, the program has little ability to expand beyond the UMaine area. We recommend broadening the dissemination of Bridge Year teaching to the area around other institutions, *provided that* resources exist to ensure the program’s success without impacting the success of other physics instruction.

We caution that successfully implementing Bridge Year courses in physics requires an engaged faculty member to work closely with high school physics teachers. We do not believe that such a person exists at any of the non-UMaine campuses, given the teaching loads at USM and UMF and the lack of physics faculty at the other campuses. Disseminating Bridge Year more broadly requires physics expertise, leadership skills, an ability to lead professional development, regular communication for the program to succeed, and, above all, the time to do the work. At the moment, only UMaine has these capabilities.

We are unsure if investing in someone to work with Bridge Year is more appropriate than investing in faculty to teach high quality courses at the University level.

E. Strengthening connections through regular communication

We firmly believe in local governance within the faculty of the existing campuses. Decisions made by the Physics Team should in no way weaken the intellectual and programmatic independence of faculty at the individual campuses. Thus, our solution to the problems listed above is to create a structure that allows existing faculty at their existing campuses to interact and collaborate to resolve issues that impede student success.

We propose an annual meeting of UMaine System (and Community College) physics instructors. At each meeting, instructors of the appropriate courses would discuss course implementation, evidence of student learning (results on exams, for examples), measures of student growth (questions used on exams), and so on. By sharing instructional and evaluation materials and being more aware of the expectations of instruction at each of the campuses, faculty would address the issue of instructional coherence across the campuses. This would ensure that students transferring from one campus to the next would have greater success in their new institutions. But, discussion of instruction would move forward collegially, among colleagues, rather than in a way that violates academic independence at each of the campuses.

The meeting would be a two-day event. On day one, we would start at noon, to allow for people to drive to the UMaine campus, which is centrally located and where most physics faculty are located (lowering travel and housing costs). A dinner would follow the afternoon's work, allowing for not just professional but also social interactions between faculty. These are essential for ongoing discussions and engaged interaction at other times of the year. The meeting would continue on day two, ending at 2 pm, giving participants time to return home by dinner.

We have avoided financial considerations throughout this report, but suggest that this two day meeting would be an inexpensive investment in a dynamic and responsive System that allows for ongoing improvements to physics instruction. Given that only about 10 to 15 faculty (depending on hiring and how many Community College instructors participate) would come to Orono, we estimate that the cost of the entire meeting could be held to under $2,500, with dinner included.

A properly designed meeting, with outcomes regarding aligned instruction and professional development around common teaching tools, would provide the entire UMaine System with answers based on lessons learned at UMaine and elsewhere. Effective local instruction would allow for differentiated instruction in the introductory courses while meeting the high standards needed for transfer students. Working with local faculty to provide coherent instruction across multiple campuses would build on the ongoing conversation around teaching methods, course expectations, and measures of student outcomes. There would be opportunities for professional development to align research-based course improvements at UMaine with dissemination to other campuses, if needed. And, funding for instruction would remain a local issue, dependent on the needs and abilities of each institution in the System. In this way, we build connections among the different campuses while acknowledging the unique status of each campus.