PLANNING, IMPLEMENTING AND ASSESSING AN INTEGRATED MATH AND SCIENCE CURRICULUM

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Introduction

In the fall of 1996, Drury College began a new integrated mathematics and science curriculum required for all non-science majors. The goal of this curriculum is to produce graduates who are literate in mathematics and science. The impetus to develop this new curriculum has been two-fold: like many others, we believe that science and mathematics literacy will be essential for citizens in the next century, and that the current pedagogy of mathematics and science education has proved inadequate at developing such literacy.

This paper describes both the curriculum we developed to address these concerns, as well as the process that led to our new courses. As we worked over the last four years to build a new approach to science and math education for our non-science majors, we discovered the importance of the planning process itself, as well as an assessment protocol that allows for revision and improvement. As we worked towards an interdisciplinary approach to math and science education, we emphasized the common ground we all shared, worked to include more and more colleagues in the design and implementation, and kept our administration informed and supportive of our effort. We hope that our experience, driven partly by chance and partly by design, may be helpful in guiding those beginning similar reform efforts.

Assessment of the Curriculum

One of our goals is to assess the effectiveness of this curriculum and its unique pedagogical elements. In order to do this, we have developed an extensive and comprehensive Assessment Protocol, which includes a student attitudes survey, a scientific interpretation test, a math literacy test, focus groups, and an outside evaluation program. This assessment enabled us to clearly identify both the strengths and weaknesses of our curriculum, as well as where students were having difficulty and where they were excelling. More significantly, our Assessment Protocol provided a mechanism for revising our curriculum to meet our educational goals.

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Assessment: Our students before...

If an institution wants to plan and implement a science curriculum that shapes attitudes for the future, it is imperative to know what notions, ideas, and conceptions are already in the minds of students when they arrive in the classroom. The attitude survey, given to students the first week of class, made it incandescently clear that we were facing significant challenges. We want our students to see that science and math are important parts of their lives, yet our assessment [Deeds 1997] revealed that over 40% of our students thought that:

- Math is boring.
- A strong background in math is not required to understand science.
- A math class is not important to take unless required for graduation.
- Learning both mathematics and science primarily involves memorization of facts.
- Everyday life requires little understanding of math or science.
- An understanding of science and technology is not required to be a good citizen.

What is surprising about these disturbing results is that almost 80% of the same students thought that science was an essential component of a liberal arts education. This may indicate an attitude toward education that implies learning is distinct and different from what will be required after graduation. Our assessment results provide even more evidence that lifelong learning must be connected to the long-term goals, aspirations and futures of our students.

Assessment: Our students during...

Every assessment program should include feedback from the students during the semester and there should exist enough flexibility in the class to make minor adjustments that reflect this feedback. Naturally, major restructuring of the course must wait until after the semester, but small changes in response to student criticisms and suggestions go far toward creating goodwill in the classroom. Early in the spring semester of 1997, faculty of the Science and Inquiry (S&I) course met with students to discuss their concerns with the course. A summary of the students' comments follows:

- Too much science was required for graduation.
- The Math and Inquiry course was of little value or relevance to the students' majors.
- Separate sections of the Math and Inquiry should be more consistent.
- More feedback to students, including graded assignments, was needed in S&I.
- Better organization of the discussion period was necessary in S&I.
- A stronger and more coherent connection should be made between the mathematics and science component and other courses in the General Education curriculum.

Revisions

Based on the assessment and feedback from the Spring Semester 1997, we have made the following revisions for our courses to be taught in the Fall Semester, during extensive summer work supported by NSF.

In Mathematics and Inquiry (MATH 203), we have focused on ensuring consistency among sections. There is now a common syllabus and a common Final Exam. Faculty meet on a weekly basis to communicate any deviations from the syllabus. More emphasis is placed on student writing, as essays are required on the topics of math anxiety; the relevance of mathematics; and the nature of mathematical truth compared with scientific knowledge. Additionally, students now have the option of resubmitting material on an exam, as a take-home exercise; in so doing, students can gain half credit for all points missed. The faculty also agreed to reduce lecture time to provide more class time for group work on projects.

Science and Inquiry (NSCI 251) was rearranged so that the module on Light follows the introductory module on atomic structure. Not only does this sequence fit naturally, but the Light module also requires a large amount of math, which should help students to make connections between this course and MATH 203 early in the semester. The DNA module has been refocused around cancer, which more closely connects with students' interest in human health (as indicated by our attitude survey). We hope this will improve their understanding of the relevance of this material. To address student concerns about the amount of

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material on exams, and corresponding anxiety about the impact on their grade, there are now four exams during the semester. Although the weight of exams in the course grade is now slightly higher, it remains lower than in many other classes. The discussion period has been more tightly structured, making use of articles from Scientific American and other assigned readings and using discussion questions which are prepared by students prior to coming the discussion. Weekly quizzes and summaries from readings are required to improve students' use of the text.

Assessment and Feedback: Does this Curriculum Work?

Our new curriculum offers a real paradigm shift, away from a stress on teaching and toward an emphasis on student learning. In addition, we have instituted assessment protocols that provide mechanisms for positive change based on student feedback. This student feedback came from year-end focus groups, conversations with outside evaluation teams, pre- and post-testing in Math 203, and student evaluations. Results after the first year are strongly encouraging.

End of year focus groups

Our focus groups revealed a consensus among students that the interdisciplinary interplay between faculty was an important and fun part of the course. Students appreciated the faculty's willingness to stop and explain concepts during lecture. They enjoyed having a large group of the faculty in the lecture session and appreciated the enthusiasm of the entire faculty involved in the course. In addition, students expressed gratitude for understanding for the first time important and fundamental concepts in science such as atomic structure, periodic properties of the elements, etc.

Outside evaluation team

Grant funds provided for a visit by five math & science educators: F. Sheldon Wettack, Harvey Mudd College; Stephanie Fabritius, Southwestern University; Fred Bowers; Spelman College, David Jackson, Dickinson College; and Sheila Tobias. This team attended individual classes of Science & Inquiry and Math & Inquiry, and interviewed students without faculty present.

These interviews confirmed the positive nature of the curriculum and its effect on our students. Students appreciated the cross-disciplinary nature of the course, and the in-depth treatment of the subjects covered. Students specifically mentioned that they enjoyed working and learning in the group-based projects, and liked the computer-based presentations and use of web-based materials. Students were also more confident about their math and science abilities and indicated that they were now able to converse with science majors. In fact, they believed that they understood the scientific method better than many science majors did. Several students also displayed excitement about continuing their work in the research course.

In their written report, the evaluators commented about the general nature of the curriculum. They thought the curriculum was well organized, thoroughly planned and on target relative to the development of mathematics and scientific literacy. They were especially complimentary of the laboratory component of Science & Inquiry.

Pre- and Post-Testing

Pre and post testing provide a gauge of student learning that is a major part of our assessment protocol. Preliminary results for the Math and Inquiry course indicated significant changes in concept understanding. The assessment showed an average percentage gain of 62% over the five concepts tested. We attribute this phenomenal gain to students actively working with concepts instead having them presented as part of a standard lecture.

Student Evaluations

Drury College conducts student evaluations that provide feedback about the success of a particular class. These evaluations are also used as part of the tenure and promotion process. The evaluations provide an overall rating of the course and the instructor on 1-5 Likert scale (1 meaning the most positive). The Math and Inquiry course as well as the Science and Inquiry course made significant improvement from the spring semester of 1997 to the fall semester 1998 showing an improvement from 2.10 to 1.84 and 1.97 to 1.75 respectively.

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Written comments from student evaluations.

- "I like best the application of math into real world situations. Being able to see how math can be used."
- "I like how it introduces a little of each kind of math. We get to do a little geometry, trigonometry, and calculus."
- "I like being able to work in groups. Sometimes I'm able to learn better from my peers."
- "Learning how to explain math instead of just doing it on paper."

In summary, our assessment process has been an integral component of our curriculum development, and much of our current success can be attributed to feedback provided by this assessment. We have a much better understanding of the attitudes our students bring to our classes. The process has allowed both student and external evaluators to provide healthy criticism, allowing us to quickly modify and improve our courses. In many respects, this feedback has been very positive and encouraging, which has helped maintain faculty morale. Also, via this process we have learned a great deal about the components of effective assessment. This will allows us to further refine our assessment protocol, which we believe will be of value to us and to other educators. In addition to improving our curriculum, our assessment has already verified that we are making significant progress toward our goals of mathematics and science literacy for our students.

Conclusion

The mathematics and science faculty at Dairy College has developed a unique and ambitious new curriculum to significantly improve the math and science literacy of our non-majors. This curriculum has required us to formulate a new paradigm concerning the education of all of our students. This paradigm emphasizes the interconnectedness of all of our disciplines in understanding our world. The pedagogy of this curriculum makes use of material that is relevant to students' lives, contains an integrated laboratory component, emphasizes small group projects, and engages all students in a semester of scientific research.

Planning, implementing and assessing this curriculum has been difficult yet rewarding, by uniting us and focusing our sense of purpose as educators. While formidable tasks remain for this curriculum to function at its highest level, we are extremely optimistic about its future. With our intensive assessment protocol, we are already learning a great deal about our progress and have begun revising our courses. As this ongoing assessment provides additional information, we believe that this curriculum will continue to improve. We are extremely grateful for all of the help that we have had along the way, both from the NSF, our administration, and from the many individuals mentioned in this paper.

We hope that our experience will be useful to others embarking on curriculum reform, whether for majors or non-majors, within a department or across departmental boundaries. If we can provide any additional information or help to you as you go, please let us know. Good luck!

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