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Academic Year Research at Valparaiso University

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Introduction

Valparaiso University has a long-standing undergraduate research program in the Department of Mathematics and Computer Science. The program was initiated in approximately its current structure in 1991, and in the past 15 years it has provided successful experiences for both students and faculty.

The VU mathematics faculty have directed undergraduate research for decades. In the early years most of these projects were set up on an ad-hoc basis based on mutual interest between individual faculty members and individual students. The level of organization of this work changed dramatically when James Caristi obtained a NASA Joint Venture grant, part of which involved engaging teams of undergraduates in research projects of interest to NASA. The grant provided scholarships to participating students. After the grant ran out the participating students urged the faculty to continue the research projects even without any real incentives to the students. They were right, and we always find students interested in learning about mathematical research.

Program Goals

It became obvious while the NASA grant was in progress that we needed to identify clear goals for our undergraduate research program in order to communicate its purpose to incoming students and to faculty members. Consensus quickly converged on the following four goals:

1. Model the research experience of mathematicians.
2. Provide a growth experience appropriate for the maturity level of the participating student.
3. Help students build meaningful connections to the faculty and the department.
4. Introduce students early in their studies to the discovery of new mathematics.

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These four goals reflect the belief of the department that, while we were providing students with research experiences, the emphasis should be on the learning experience rather than on the production of publishable mathematical results.

Program Structure

The program has two distinctive features that determine the other structural components. First, students commit to working on a project for a full academic year. The participants can receive one credit in each semester for the project, although in our experience, some students do not register even though they participate. Theoretically a student could obtain eight research credits during their studies; however, this almost never happens. Most students do not participate in the program every year, and many who do participate do not register for credit later in their studies. Many of our majors are double majors, spend a semester abroad, or participate in internships. It is quite common that a student participates in research one or two years out of the four years they spend at Valparaiso. Those students who pursue graduate degrees in mathematics or computer science usually participate for at least three years. In the last four years the department directed 13 projects and students registered for 75 credit hours during this period.

The second notable feature is that students work in vertical groups. These groups usually consist of 3-4 students including at least one freshman and one upperclassman. We direct 4-6 groups each year, and approximately 30% of our freshmen majors participate.

Each summer the incoming freshmen mathematics and computer science majors receive a letter of invitation to the program. If interested, the students apply with a personal statement about the nature of their interest and current professional goals. As we are interested in engaging all interested students in research, it is very rare that an application is turned down. When a student is turned down, it is usually due to the student being overcommitted with extracurricular activities (band, theater, sports, etc.) during their first year on campus. We talk to these students and recommend that they reapply after a year if they think they have time for the research project.

Upper classmen are recruited several ways. Some students will have participated in the program earlier and they request to stay in, or to re-enter the program. Individual faculty recruit others based on a class experience with them. And still others approach a faculty member and express interest in participating in a project, and occasionally, an upper classmen has an idea for a project and asks a faculty member to direct the project.

One student, whose path through the program is typical, participated in a project as a freshman, played baseball as a sophomore, participated in another project as a junior and then spent one semester of his senior year abroad and the other one student teaching. One of our recent graduates, who is currently working on her PhD in mathematics, participated in four research groups, and each of these four projects resulted in a refereed publication.

We make an attempt to match the interest of the students to available projects and we try to balance personalities in the groups. We expect the students with

different maturity level to play different roles in the groups. Freshmen and sophomores are responsible for understanding the project, and generating examples and counterexamples. Sophomores and juniors are responsible for the literature search, and making conjectures. Juniors and seniors are responsible for generating and proving conjectures. As our goal is to introduce students to the "trade" of mathematical research, we follow the apprentice model. We explain the students these different roles and let them know how the expectations are different for the apprentice, journeyman, and tradesman who all work under the direction of the professor, the master craftsman.

The groups meet weekly for about an hour during which every member presents their progress for the week. The group evaluates their progress together and sets new goals for the following week. It is important that every person in the group has a clearly defined task when (s)he leaves the meeting.

We expect that every project finish with a written report that resembles a mathematics paper. If the group solves their problem, and/or their progress is worthy of publication the faculty advisor submits the results for publication. However, producing publications is not an expected outcome of the projects. We encourage our students to present their results at local, regional and national meetings. At the minimum, the groups present posters at the Valparaiso Celebration of Undergraduate Research. Our students regularly present at Indiana section meeting of the MAA, the Butler University Undergraduate Research Conference, and at the Rose-Hulman Institute of Technology Undergraduate Research Conference. Occasionally, students will present at MathFest, NCUR and NCTM national meetings.

Project Features

Just as with any other undergraduate research project it is important that the problem can be easily explained to the participants, including the freshmen. Good projects provide immediate access to examples, either computer generated or pencil and paper examples that the students can find and play with. It is useful if the problem has some literature in order for the students to experience literature search, however, it is also useful if the problem has not been studied extensively. Naturally, it is unlikely that undergraduates will make progress on the major conjectures of any field. The solution or study of the research problem should require the study of new mathematics for every member of the group including the seniors. For a successful research experience for everyone involved, it is essential that the problem is interesting for the faculty sponsor of the group.

Many of our projects are resulted from faculty members looking at the world around us in a mathematical way. Some recent projects included modeling ground water flow problems, investigating a generalization of the segregation game studied in social work, studying social mixing, or seating arrangements, creating visual results for computer information retrieval systems, researching the teaching and learning of Differential Equations, generating probabilistic word-square puzzles, exploring colorings,labelings, and pebblings on graphs.

Timeline

As mentioned before, each group works for an academic year. It seems that the projects have very similar life cycles. Usually the first half of the first semester is spent on understanding the problem, conducting literature search and generating basic examples. The second half of the first semester is the time to try out ideas, generate conjectures and hit roadblocks. Christmas break provides a good opportunity to step back from the problem. By the second semester the students are usually eager to get back to working and the first half of the second semester is where breakthroughs happen (if ever). This semester is the most productive in generating new mathematics. The second half of the second semester tends to be very busy for everyone involved, and it is the perfect time to learn about the difficulties involved in writing a mathematical paper. In March and April students present their results at the various conferences.

Benefits

We have no formal instrument for assessing the effectiveness of the program. Based on informal questionnaires and discussions with participants, we believe the program meets its goals as stated earlier in this paper. Students have a different view of the program as the faulty does, and they emphasize different benefits. We often hear that the research project brings the student into the department early on. It provides a connection to a faculty mentor and makes the student feel more at home in the department. Students often state how the view of mathematics they see while working on research projects is different from traditional classroom material.

Students usually do not claim that the research experience radically change their post graduation plans, however, they do say that it has a significant impact on their course of study at the university. Of course it is very difficult to measure the impact of the program on postgraduate plans, as freshmen very rarely know what they plan to do after graduation.

It is interesting to note that students generally do not consider the fact that they get academic credit for the experience important. Many of the students ask for recommendation letters from their former project directors, and the personal connections developed over the year enables faculty to write detailed and meaningful letters of recommendation.

Almost everything mentioned as a benefit for the students can also be considered as a benefit for the participating faculty members. Mentoring students in our profession, building personal connections, conveying the true nature of mathematics are all goals we aim for as teacher-scholars. In the past three years a participating faculty member has received one-hour teaching credit for each year-long project directed. This means that after directing 3 year-long projects the faculty member can receive a course release. This benefit has been available for the last 3 years of the 15 years of the program. Although it is very much appreciated by the participating faculty, we find that it has not been a motivational force for anyone. Faculty members usually volunteer to direct a group when they have a project in mind regardless of the existence of the teaching credit.

Conclusion

The approach that we've taken here at Valparaiso University is somewhat unorthodox, since it is rare that freshmen college students have sufficient mathematical tools to solve research problems. However, as a department that values undergraduate teaching and learning, we realize that our principal goal is not to produce publishable mathematics (a great result when it happens), but rather to produce graduates who are capable and ready to excel both in graduate school and in the workplace.

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