COMPUTATIONAL ASTRONOMY: A NEW WAY TO TEACH MATH AND SCIENCE IN MIDDLE/HIGH SCHOOLS ACROSS SOUTH DAKOTA

D. Kliche[1]*, M. Garlick[1], D. Teets[1], P. Grieve[1], T. Kowalski[1], M. Gregg[2], N. Grau[2], C. Olimb[2], L. Sun[2], and Judy Vondruska[3]
[1]South Dakota School of Mines and Technology
Rapid City, SD 57701
[2]Augustana University
Sioux Falls, SD 57197
[3]South Dakota State University
Brookings, SD 57007
*corresponding author email: donna.kliche@sdsmt.edu

ABSTRACT

The Computational Astronomy-2 project is focused on engaging middle/high school teachers and students in learning about NASA's space exploration through familiarization with astronomers' computational principles. The theoretical basis for the project was to inspire middle/high school math teachers to include relevant science examples in their classrooms and, correspondingly, science teachers to include more math applications in theirs. The scope of this new approach was to stimulate in students' minds a deeper understanding of the importance of mathematics and its relation to scientific exploration. Fifteen in-service teachers from the following South Dakota school districts participated at the summer 2019 workshop: Arlington, Scotland, Centerville, Oglala, Burke, Meade, Redfield, Rapid City, and Spearfish. Out of all participants, five were middle school teachers (one teaching science and the other four teaching math), and ten were high school teachers (five teaching science and five teaching math). Our final survey showed that nearly all participants gained content knowledge during the workshop. In the fall 2019, several participants implemented the lesson plans provided during the workshop in their classrooms. During the Fall 2019 and Spring 2020, South Dakota School of Mines and Technology faculty and two undergraduate students visited the two largest high schools in Rapid City (Central and Stevens) and conducted an activity from the Computational Astronomy lessons to several "Exploring Computer Science" classes. Overall, more than 500 students were exposed to these computational concepts. This STEM effort was received with great enthusiasm by both teachers and students.

Keywords

STEM education, computational astronomy

INTRODUCTION

Mathematical principles are the building blocks of science, but math is often an obstacle for students in working toward their goal of becoming an engineer or a scientist. Student math and reasoning ability can be improved by helping students see the application of math principles in their science courses (National Research Council 1996). Applying their math knowledge across the STEM fields will not only expand their experience with the subject matter but also help increase their ability and confidence in it.

Teaching math and science disciplines together has long been recognized as good practice. Arnett and Horn (2009) found that the learning community that teaches math content in the context of science addresses the needs of math-phobic students in a supportive and relevant way. More and more educators have realized that science and mathematics teachers should work together (RAND 2012) to provide more chances for students to develop keenly interwoven knowledge.

Professional development (PD) and continuing education are a necessity to update in-service teachers' content knowledge, provide support to those navigating out-of-field teaching appointments, and encourage the adoption of new pedagogy that supports incorporation of Common Core and Next Generation Science Standards (Desimone 2009; Newman et al. 2012; Allen et al. 2011; Gallagher et al. 2017). During 2019, South Dakota School of Mines and Technology (SDSM&T), South Dakota State University, and Augustana University combined their efforts to propose (and seek funding for) a new type of professional development workshop to engage middle/high school teachers and students in learning about NASA's space exploration through familiarization with astronomers' computational principles. The theoretical basis for the project was to provide middle and high school math and science teachers with math applications employed in space exploration that they can share with their students to stimulate deeper understanding.

The three-day computational astronomy workshop was held on the SDSM&T campus in June 2019 and was delivered as a one-credit continuing education for the K-12 Science and Math teachers for certification renewal. The stated workshop objectives were for participants to: 1) Discover the importance of basic computational principles used by astronomers. 2) Understand and apply mathematical concepts and apply them to specific examples from astronomy. 3) Identify various astronomy applications and ways to engage students to improve their understanding of mathematical concepts.

During the workshop, teachers learned specific computational examples linked to astronomy. Topics included -- planets and the Kepler's laws, New Horizons mission to Pluto, relativity using basic algebra and geometry, vector math, predicting an International Space Station sighting, Stellar Brightness, the James Webb Space Telescope, applications using Desmos (free online graphing calculator) and Stellarium software (simulates the nighttime sky), space weather, and mathematical modeling. The material focused on the close relationship between math concepts and space exploration, as well as on the importance of mathematical modeling. Presentations of these topics by University faculty were

accompanied with specially prepared lessons for middle and high school teachers to implement in their classroom. In addition to formal classroom work, participating teachers attended one night of telescope observations of Jupiter and the Galilean moons at the Black Hills Astronomical Society site near Rapid City.

Through the Fall 2019 and Spring 2020, a faculty member working on the project continued to have in-class sessions at the two largest high schools in Rapid City: Central and Stevens high schools. The faculty member was accompanied by two SDSM&T undergraduate students who presented examples of space exploration. In addition, high school students were engaged by using the Excel software and writing small programs in Python to display and interpret selected NASA data.

METHODS

The summer 2019 workshop for teachers began with a pre-survey to gather information about the participants and their interest in the course. Demographic information collected included gender, race, and undergraduate/graduate degrees earned. Questions about their teaching experience included the number of years of teaching, where they teach, and the grade level and courses they teach. There was also a question assessing their experience in teaching the topics to be covered in the workshop. The questions about the workshop included how they heard about the course, how important it was that they earned graduate credit for participating, and how important the stipend was to them for covering expenses. The survey ended with general interest questions about their astronomical experience (such as identifying constellations or seeing the International Space Station), their favorite space show or movie, and the subject they would most like to teach.

The participants were asked to complete a post-survey at the end of the workshop. The purpose of this survey was three-fold: to gauge the quality of the experience for the participants, to assess the knowledge gained from the presentations, and to identify teacher willingness to implement modules from the workshop in their classes and report the results. Participants were asked what they liked best about the course, what they thought was most valuable, and what they wished would have been part of the workshop. Nine of the survey questions were related to the workshop lecture material. Teachers were asked how they might use the workshop materials in their classrooms, and in what courses/grade level were they most likely to implement any of the modules. Finally, we recruited teachers to implement selected lesson plans, and we designed feedback forms for teachers to record their experience in the classroom.

RESULTS AND DISCUSSION

Fifteen in-service teachers participated at the summer 2019 workshop from the following South Dakota school districts: Arlington (1), Scotland (2), Centerville (1), Oglala (1), Burke (1), Meade (2), Redfield (1), Rapid City (5), and Spearfish (1), with the number in parenthesis representing the count for teachers attending the workshops. Five were middle school teachers (one teaching science and

the other four teaching math), and ten were high school teachers (five teaching science and five teaching math). In the fall 2019, two teacher participants implemented selected lesson plans from the workshop in their classroom. They provided valuable feedback and helped to improve and adjust the prepared lessons to fit the South Dakota curriculum requirements. The number of students reached through the teacher participants to the summer workshop can be estimated as about 150 middle school students and about 300 high school students (if we consider these teachers are each teaching only one class of 30 students, although each teacher usually teaches more than one class). The results of this effort were also presented at the annual Math and Science Teacher Conference in February 2020 in Huron, SD.

The post-survey showed that over 70% of the attendees had participated during or before the workshop in astronomy related activities such as using a telescope, seeing the moons of Jupiter, and holding an object from space (a piece of a meteorite). A majority of participants reported having a better understanding of concepts such as Kepler's law, computation of planetary masses, relativity, the vastness of space, how to use DESMOS (an online graphing calculator), and how to introduce mathematical modeling to students.

Overall, the participants appreciated the hands-on activities and the use of software like Excel, Desmos, and Stellarium. They appreciated the instructors' enthusiasm and expertise. The suggestions for improvement included allowing more time to process and think about the material and to discuss it with colleagues.

Some key aspects of the feedback received from teachers attending the June 2019 workshop are shown below (in their own words). They answered the question of what they liked during the workshop and what they would like to see more of in future workshops.

> *"The host of lesson plans/ideas that I can realistically incorporate into my classroom next year."*
>
> *"with more ideas to become a better teacher."*
>
> *"The astronomy aspect with Desmos to get students engaged in hands-on activities while integrating geometric concepts (and the instructors were outstanding!!)"*
>
> *"All the ideas (e.g., DESMOS, use of Excel, Stellarium) to do real-life investigations of the universe. It really brings the excitement of math alive to us. It will be great to share this with students and friends."*
>
> *"More computer science coding. More hands-on material (supplies, handouts) to take back to the classroom."*

The questions specific to workshop topics were answered correctly by more than 70% of the teachers, demonstrating growth in content knowledge achieved as a result of participation. A question about the space station was answered cor-

rectly by all the participants as well as a question about twins aging relative to each other. A question about Lagrange points was answered correctly by 93%. Right answers were given by 86% of the participants in response to questions about relativity, the James Webb telescope, and the length of an eclipse cycle. Questions about math modeling were answered correctly by 73%.

Out of 15 participants, four expressed interest in implementing a module in their classes in the fall of 2019. Two teachers, one high school and one middle school, followed through and used a lesson plan from the workshop in a class. They provided feedback and a sample student work. The high school teacher used the lesson, "Measuring the Size of the Solar System with a Telescope" in two sections of an astronomy class (students from 10th-12th grades). The students were amazed at the simple tools needed to determine distances in space. The complaints from students were about the amount of math involved. The varied math backgrounds of the students were a challenge for the teacher. Overall, the teacher felt the lesson was well received.

The middle school teacher used the lesson plan "Sunspots and Satellite's Decay" for twenty-five 7th and 8th grade students. Most of the students said they liked the lesson and would like to do something like it again. The teacher felt the lesson was absorbed well by the students. The biggest benefits were the students' interest in how solar weather affects us on earth. The result was that 88% of the students finished with over 70% accuracy on the assessment following the activity.

In the Fall of 2019 and Spring of 2020, two largest high schools in Rapid City (Central and Stevens) were visited and introduced to more in depth applications for the Computational Astronomy selected for the special presentations to their "Exploring Computer Science" classes. Such classes included mostly sophomores and juniors and a few senior students, while gender representation consisted of 2/3 boys and 1/3 girls. For Central High school, we visited the classes twice a week to accommodate their block schedule, a 1.5 hours block. Stevens class has the regular 50 minutes long class session, and we went 3 times a week in order to complete the presentations that included content related to space exploration and hands on experience for the students with real data manipulation and interpretation using Microsoft Excel and Python software. The lesson was focused on finding a possible correlation between the average sunspots number and the number of satellites decaying each year from 1969 to 2004 (these data were found on the NASA website).

At the end of each presentation we handed out to students short surveys that had questions related to satellites, space weather, whether or not they liked math and/or science, familiarity in using Excel spreadsheet and Python programing to analyze data. The post-session surveys consisted of 14 questions for high school students and had four different answer options: "Yes", "No", "Maybe" and "Other". Each time we asked the students if they liked the presentation, their response was "90% +" an enthusiastic "Yes".

Future Work—The workshop was a learning experience for the presenters as well as the participants. Even though the teachers enjoyed the variety of topics covered, many suggested that it was a great deal of information to be given in a such limited amount of time. We learned that more time is needed for teach-

ers to participate in the activities and to process the information. Also, teachers would appreciate time built into the workshop to discuss and collaborate with their colleagues, allowing them to modify the material to adapt it to middle or high school classes.

At the South Dakota Math and Science Teachers' conference in February 2020, held in Huron, there were three presentations related to the Computational Astronomy project. Examples of lesson plans were demonstrated with the teachers in attendance playing the role of students. The response from the teachers was overwhelmingly positive, and they showed large interest in participating in future workshops with this topic.

With additional South Dakota Space Grant Consortium funding, we were scheduled to deliver another three-day workshop in June 2020. However, due to the COVID-19 outbreak, we are adapting the workshop to an online delivery starting Saturday, September 5th. We will modify the overall delivery into three-hour sessions over six Saturdays during the fall of 2020. Since this is going to be an online class, we will encourage interaction among participants and the project team through collaborative adaptation of some of the curriculum presented in the workshop for classroom delivery. Discussions and collaborations will be facilitated during additional once-a-week evening sessions.

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