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Infographics and Mathematics: A Mechanism for Effective Learning in the Classroom

Ivan Sudakov
University of Dayton, isudakov1@udayton.edu

Thomas Bellsky
Aalto University

Svetlana Usenyuk
University of Maine at Orono

Victoria V. Polyakova
Ural Federal University

INFOGRAPHICS AND MATHEMATICS: A MECHANISM FOR EFFECTIVE LEARNING IN THE CLASSROOM

I. Sudakov

Department of Mathematics, University of Utah, Salt Lake City, UT 84112-0090, USA

sudakov@math.utah.edu

T. Bellsky

Department of Mathematics and Statistics, University of Maine, Orono, ME 04469, USA

thomas.bellsky@maine.edu

S. Usenyuk

School of Arts, Design and Architecture, Aalto University, Helsinki, 00560 Finland

svetlana.usenyuk@aalto.fi

V. Polyakova

Department of Applied Sociology, Ural Federal University, Ekaterinburg, 620002 Russia

vika.polyakova@urfu.ru

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Biographical Sketches

Ivan Sudakov is an assistant professor of physics at the University of Dayton. In 2012- 2015 years he has been a research assistant professor of mathematics at the University of Utah. Ivan has got his Master degree in physics and PhD degree in mathematical modeling. He specializes in mathematics and physics of the climate system. He tries to develop the tipping point theory applied to the Arctic region. He has been awarded numerous fellowships such, as for example, Edward Lorenz Fellowship, Isaac Newton Institute Visiting Fellowship or Nansen Fellowship. The German Federal Government awarded him the title ”green talent” in 2013 year.

Thomas Bellsky received a Ph.D. from Michigan State University in 2011 under the guidance of Keith Promislow. Tom is currently an assistant professor in the Department of Mathematics and Statistics at University of Maine. Previously, he has been an Ed Lorenz Postdoctoral Fellow at

Arizona State University with the Mathematics and Climate Research Network. His research interests include dynamical systems, stability theory, data analysis, parameter estimation, uncertainty quantification, and weather and climate forecasting. His current research focuses on rigorously establishing the existence and stability of localized structures arising from coupled fast-slow reaction-diffusion equations. Additionally, he is developing data analysis and parameter estimation techniques to better forecast solutions to conceptual climate models.

Svetlana Usenyuk is a Postdoctoral researcher at Aalto University School of Art, Design and Architecture, Helsinki, Finland. Prior to that, she was a doctoral student and part-time teacher at the School of Arctic Design, i.e. a special unit of the Ural State Academy of Architecture and Arts, Ekaterinburg, Russia, that hosted research projects with focus on the cultural and environmental impacts of human activities in the Arctic areas. Her professional interests also include artistic experimentation and exploration in the field of university teaching.

Victoria V. Polyakova is an assistant professor of applied sociology at the Institute of Social and Political Sciences of the Ural Federal University and she holds a PhD degree in Sociology. She specializes in the study of the higher school problems, improving the quality of the education and the development of new form of exams. She conducts sociological and statistical research into the study of the education and the modern family problems.

Abstract: This work discusses the creation and use of infographies in an undergraduate mathematics course. Infographies are a visualization of information combining data, formulas, and images. This article discusses how to form an infographic and uses infographics on topics within mathematics and climate as examples. It concludes with survey data from undergraduate

students on both the general use of infographics and on the specific infographics designed by the authors.

Keywords: Infographics, mathematics, undergraduate education, climate science, educational technology

1 INTRODUCTION

Infographics are visual representations of information, data, or knowledge intended to present information quickly and clearly [2, 8]. Infographics can improve cognition by utilizing graphics to enhance the human visual system's ability to see patterns and trends [10]. A high-quality infographic presents complex data in an aesthetically pleasing and simplistic format that allows students to formulate understanding more rapidly.

An infographic consists of images combined with knowledge designed in a manner to efficiently communicate information to the audience [10]. Infographics are an engaging way to condense material into a more readily clear and accessible form. While many infographics focus on current events and technology trends, infographics are also becoming more common as an educational tool. In particular, there exists research based evidence on infographics improving learning outcomes in mathematics courses [9]. There are many opportunities for incorporating infographics into the classroom including using existing instructor-created visuals in an 'eye-popping' manner to arouse student interest or assigning students to create their own in order to motivate active learning and creativity.

This manuscript discusses how to form an infographic in an educational setting. This work makes use of a series of infographics from topics on (undergraduate) mathematics and climate as a guide for the design and implementation of infographics in the classroom. It

concludes with survey data from undergraduates in mathematics on the use of infographics for educational purposes.

2 DESIGNING INFOGRAPHICS FOR THE CLASSROOM: INNOVATIVE TOOLS FOR INSTRUCTION

Past experience shows the success of infographics in explaining modern mathematical problems. For example, during the World Mathematical Year 2000, a sequence of posters designed at the Isaac Newton Institute (INI) for Mathematical Sciences was displayed month by month in the trains of the London Underground [7]. The main goal of the INI campaign was to bring mathematics to life, illustrating the wide applications of modern mathematics in all branches of science: physical, biological, technological, and financial. The Joint Policy Board for Mathematics (JPBM) promotes Mathematics Awareness Month each April [4]. Their goal is to increase public understanding and appreciation for mathematics. The primary objects that the JPBM utilizes to promote awareness are infographics. Additionally, the American Mathematical Society provides a series of posters promoting appreciation and understanding of the role mathematics plays in science, technology and human culture so called Mathematical Moments [5]. Thus far, infographics have been used as a successful tool for mathematics outreach.

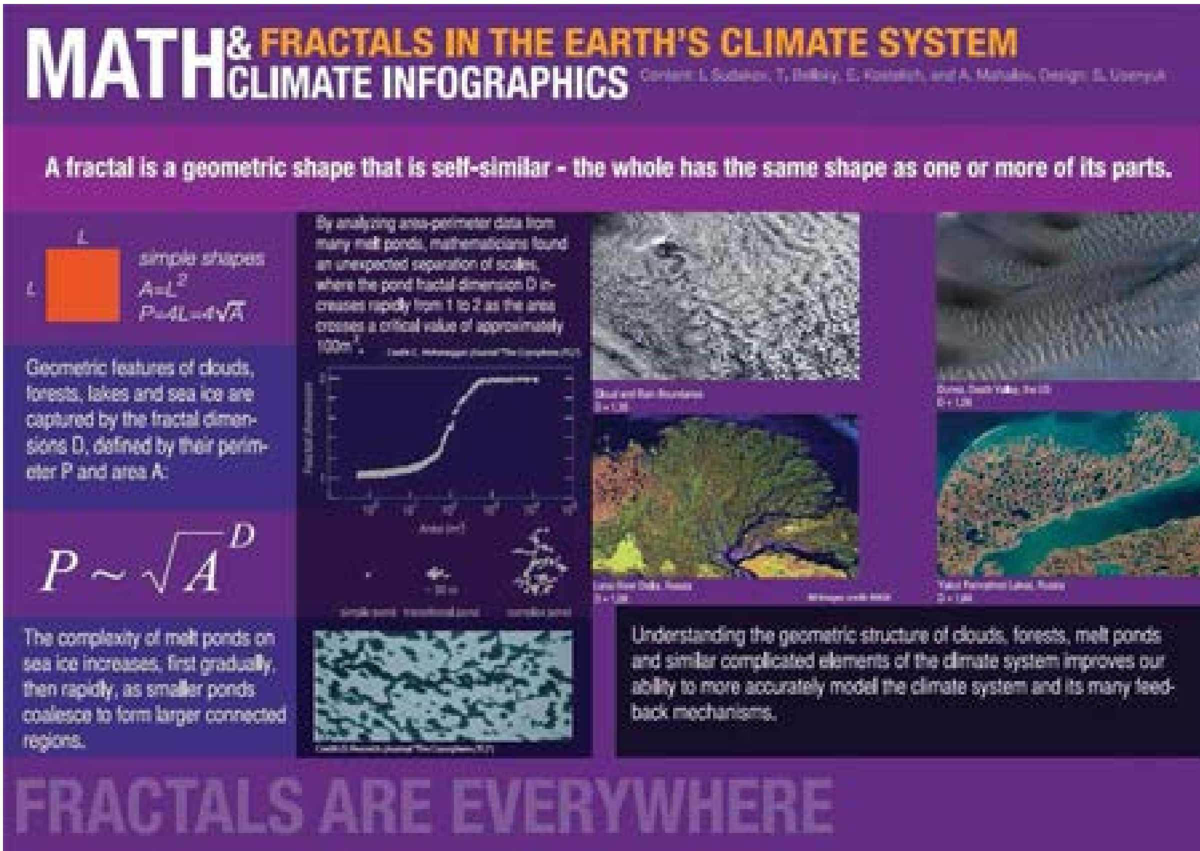
Infographics are also effective in the classroom to transmit information and to foster student interest. Pedagogically, an interesting infographic can be used to convey ideas by quickly introducing a new topic or to give a broad overview of a new subject. It can be used as a discussion starter, where students can answer questions or speculate about the given subject material. An infographic can also be used as a starting point for more in-depth research.

The formation of an infographic is similar to that of writing a paper, where the author carefully formulates a specific idea to convey. Often in the case of an infographic, the topic will lend itself well to images and visualizations of data. An infographic should aim to use appealing color combinations and arrange borders and space to provide a strong visual impact. Formulas and graphics, in combination with images of the topic under discussion, are thus used to convey an understanding of various facets of the central idea under discussion. Typically, an infographic is used as an introduction or a summary of a topic. Thus, it is important to be concise and succinct in the presentation of the material, so the learning audience will have a quick and accessible opportunity to learn.

To provide examples on forming infographics within the mathematics classroom, we make use of our own particular set of infographics. These infographics cover topics in math and its application to climate science such as fractals in sea ice, urban effects on climate, chaos and ensemble forecasting, and the greenhouse gas effect. These infographics are designed to be used within an undergraduate mathematical course, particularly within a topics course on "Mathematics and Climate" [3].

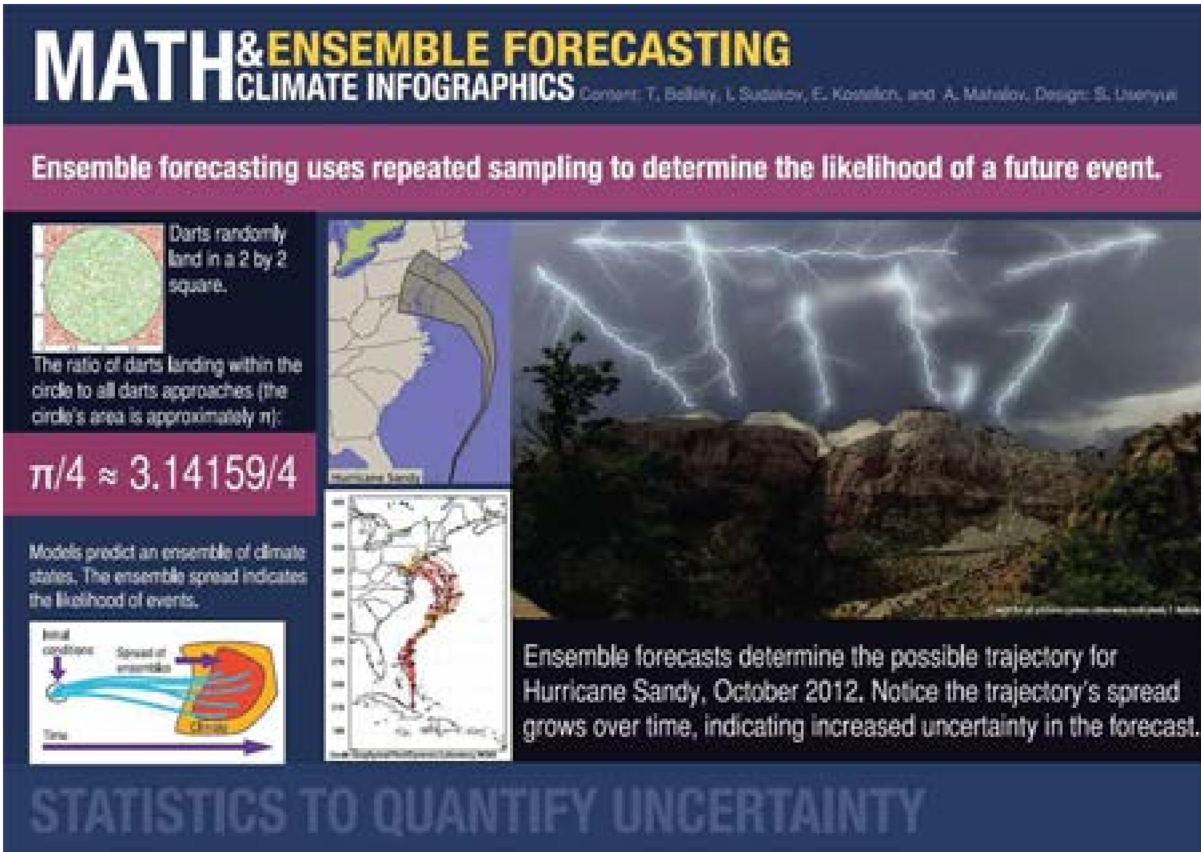
The infographic in Figure 1 discusses the mathematical concept of fractals and how fractals relate to issues within the Earth's climate system. This infographic first provides a quick definition of the mathematical topic under discussion (in this case fractals), which is important to frame the central idea. In large print, a formula is presented that describes the fractal-like nature of objects in nature. This succinct mathematical statement, at a level of mathematics accessible to a wide audience, is then further illustrated in the remainder of the infographic. When forming an infographic, it is important to provide relevant images of the (mathematical) topic under discussion, where this infographic includes images of clouds and river deltas and discusses their fractal dimension. Relatively simple visual examples are typically a strength in an infographic.

Figure 1. This infographic discusses fractals and their presence in climate phenomena. It presents a modern development of how fractal geometry is used in the problem of Arctic climate change by studying the fractal dimension transition of melt ponds.



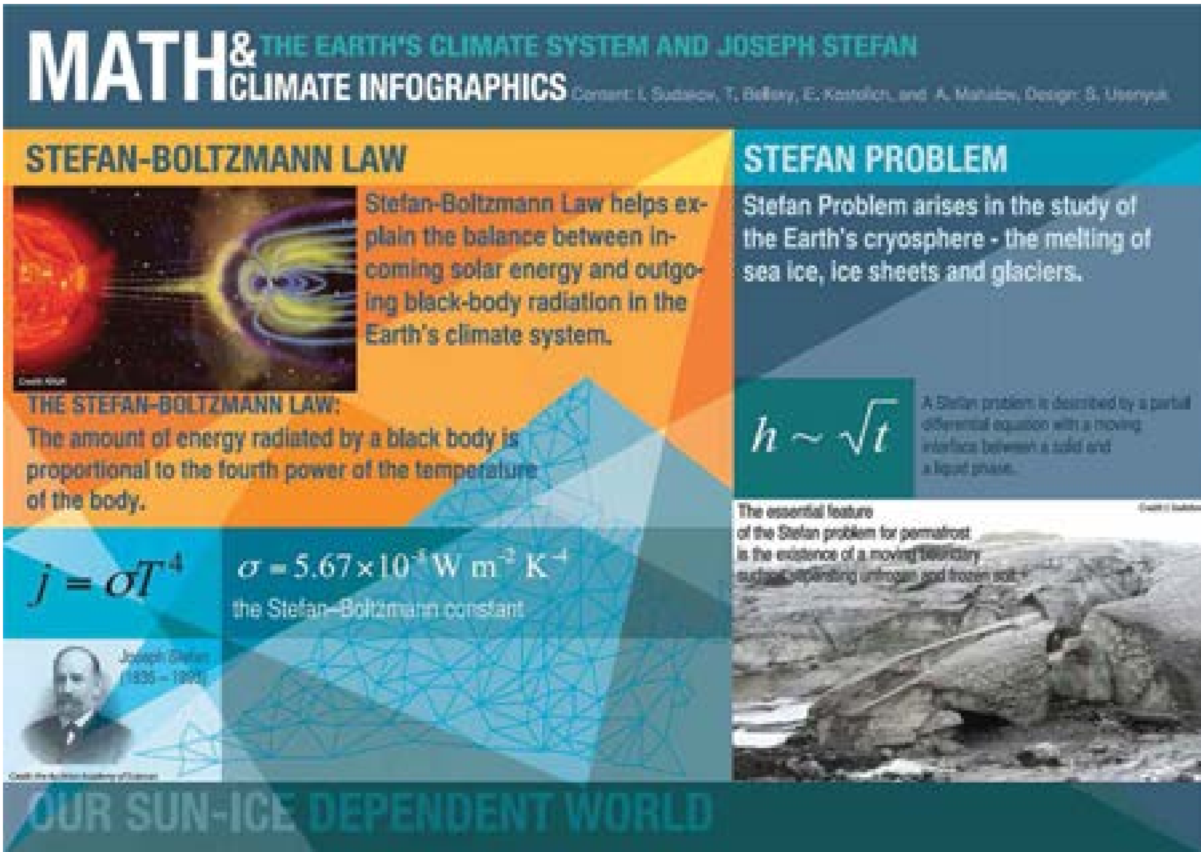
The infographic in Figure 2 describes how statistical methods are used to forecast future events, where it introduces the concept of ensemble forecasting and how ensemble forecasting is used to determine the certainty of weather forecasts. When introducing new mathematical ideas in the classroom with an infographic, it is useful to discuss applications with which students already have a passing understanding (in this case the trajectory of Hurricane Sandy). This example first introduces Monte Carlo methods, by discussing how π can be estimated by a large quantity of random darts thrown at a square with a circle inscribed. Next, this infographic discusses how this process is used within hurricane forecasting. As with writing most learning tools, it is useful within an infographic to present multiple examples of a topic. Here, the goal of this infographic was to quickly transmit a statistical topic in a short period of time. Used within the classroom, it would be a discussion starter for the day’s lesson. Since infographics are often used as a quick transmission of information, another point of emphasis when designing an infographic is to minimize textual information.

Figure 2. This infographic discusses ensemble forecasting with applications to forecasting hurricanes.



The final example in Figure 3 describes both the Stefan-Boltzmann law, the basis of planetary energy balance equations, and the Stefan problem, which is used to study melting processes of ice. When creating an infographic, it is advantageous to use graphics software to form interesting backgrounds such as combining geometric objects with color designs. In this example, particular emphasis was placed on the juxtaposition of the orange glow of the sun with the blue hues of ice (the two key topics of this infographic). Infographics can also be used to give the connectedness and history of a particular topic. In this example, the contribution of Stefan's work to modern science is a demonstration of interdisciplinary collaborations between physics, mathematics, and climate science.

Figure 3. This infographic discusses Joseph Stefan's contribution to the study of "warm" and "cold" processes in the climate system.



The examples above were formed in support of the Mathematics of Planet Earth (MPE) [6], where a goal of MPE is to involve high school and college students in mathematics and climate science through new educational materials developed for mathematics courses. This collection of twelve infographics is freely available for classroom use at the authors' respective websites.

Besides using infographics for classroom instruction, they can also be useful as student projects. Students can design infographics to demonstrate their ability to fully learn a topic and summarize its central themes in a concise manner. The authors envision using the above infographics in a topics course throughout the semester to introduce daily topics, but also to inspire students in forming infographics for semester projects.

When making a series of infographics, it is important to maintain a central style of design to make them complementary. Each of the previously discussed examples makes similar use of space, with titles, a quick definition, and a catch phrase all in the same location. Using a particular color and background theme in each individual infographic is a strategy to make them separately distinctive.

One great resource for creating infographics are images from internet search engines. This can be particularly appealing for student projects. Of note, when designing an infographic for distribution, it is important to determine the copyright status of images used within an infographic. In this case, many scientific sources provide for the free distribution of images for non-profit educational uses.

Many topics in the undergraduate mathematical curriculum could make use of infographics both in the classroom and to increase interest in mathematical topics through outreach. Infographics are also useful at the high school level to peak interest in future undergraduate studies. Additionally, infographics are useful for more advanced students as a quick review of particular mathematical topics.

3 SURVEY DATA OF UNDERGRADUATE STUDENTS ON INFOGRAPHICS

As part of this project, we have sampled undergraduate students about using infographics in the educational process. A total of 38 undergraduate students were polled, all either mathematics majors or majors within the natural sciences. In addition, the polled students represent two countries: the United States and the Russian Federation (37% and 63% respectively). Among the respondents, there were more females than males (65% vs. 35%). Also, a significant number of the polled students (87%) were seniors who had already completed a substantial number of courses in mathematics and science. This survey shows interesting results about the quality of education, diversity in teaching methods, and new forms of visualizations in educational processes.

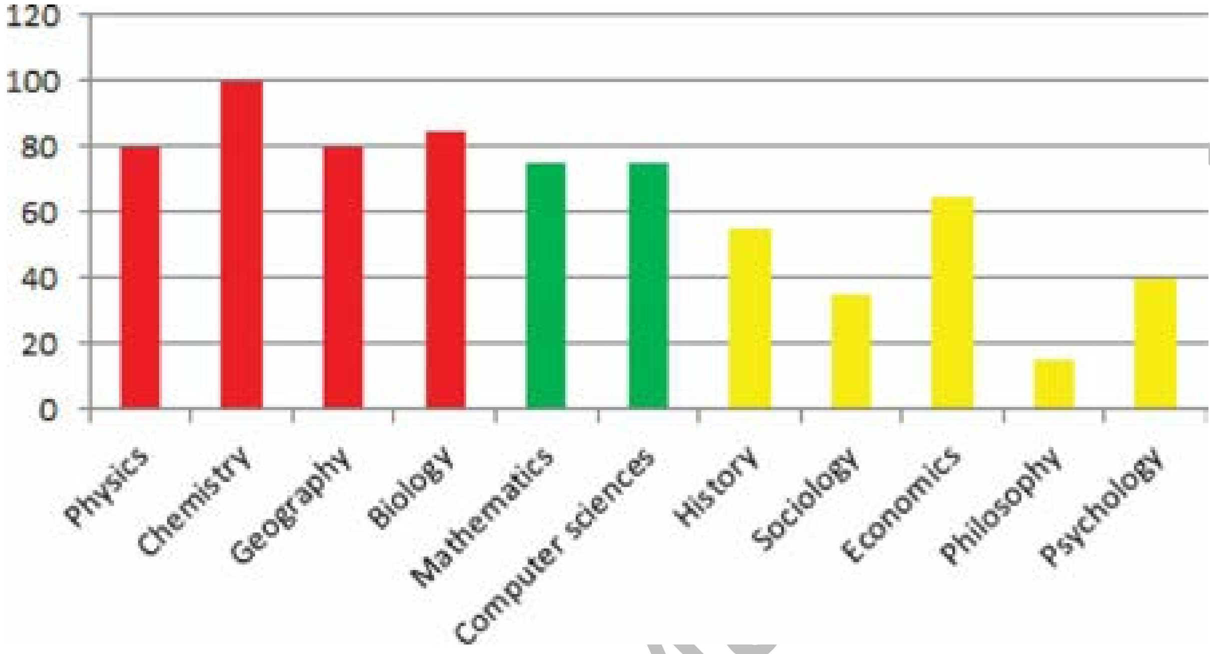
Surveyed students identified significant difficulties in learning within undergraduate courses as:

- too much information: 53%,
- too few illustrative examples: 35%, and
- difficulty in perceiving information solely from lecture: 35%.

All of the selected difficulties above are associated with the need to improve properties like "visualization" within classroom materials, where these difficulties can be addressed by using infographics as a learning aid.

The students were surveyed about the general use of infographics in the classroom. According to polled students, the importance of infographics is highly dependent on a field of the study. As visualized in Figure 4, the surveyed students emphasized that the introduction of infographics in the educational process is useful for courses in the natural sciences such as chemistry, physics, geography, biology, general mathematics courses, and theoretical computer science. Surveyed students found infographics to be less useful in courses within the social sciences such as sociology, philosophy, and psychology.

Figure 4. Percentage of polled students that felt infographics would be a useful learning aide by discipline.



More than 80% of surveyed students have a positive attitude to the introduction of infographics in the educational process. A little less than half of the respondents (45%) have previously encountered infographics in their undergraduate studies. Half of the students (50%) polled believe infographics to be a desirable and effective tool in the educational process to increase interest and learning within the mathematical sciences. In addition, 18% of the surveyed students responded that infographics have been used in their courses across many disciplines. Table 1 further presents surveyed students' responses to the importance of infographics in the educational process, where each student identified one of the five options.

Table 1. Importance of using infographics, (% of respondents)

Importance	**% of respondents**
Provide a visual representation of material	32.4
Contribute to a better perception of complex information	26.5
Appropriate for the material of the studied course	23.5
Concisely present a wealth of information	14.7
Infographics are useful in all of the above	2.9

Next, students were polled about the particular infographics of the authors. Respondents noted advantages of these mathematics and climate infographics as:

- Infographics are a brief presentation of a wealth of information: 65%,
- Information is demonstrative and readable: 40%, and
- Infographics show the relationship between different phenomena: 30%.

Students emphasized the weaknesses of these infographics as:

- Information is not straightforward enough to understand: 17% and
- Infographics are overloaded with details: 15%.

More questions were asked with regards to the general use of info-graphics in the classroom. According to respondents, instructors who use infographics must have a certain set of competencies:

- creativity: 70%,
- a deep knowledge of the material in the discipline: 60%,
- ability to analyze information: 55%, and
- fluency in a variety of software programs: 35%.

In summary, these survey results show that students find infographics to be useful in a mathematics course to achieve student learning and understanding.

4 DISCUSSION

In keeping up with current technology and learning styles, the use of infographics can be an useful tool in the classroom. In this article, we have discussed how to form effective infographics. Furthermore, we have provided student survey data that offers evidence that students find infographics to be useful in learning.

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