Evaluating Learning Effectiveness Using Generalization Techniques: Online, Traditional, or Hybrid Lectures?

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Abstract: The contemporary education environment raises questions about the effectiveness of online courses, particularly as compared to traditional classroom learning and in relation to individual student needs, perceptions, and learning outcomes. This study is designed to determine if online or traditional lectures are better for learning cartographic generalization techniques. A prevailing thought is that it is often through conversation, discourse, discussion, and debate among students and between instructors and students that a new concept is clarified. I researched learning effectiveness where the objectives were to determine which methods are best for specific generalization techniques and also to determine if students learn the techniques better online, in a traditional lecture, or a blend of both. The cartography course at the United States Military Academy (EV378 – Introduction to Digital Cartography) uses inquiry-based learning and ESRI's ArcGIS software to present both the art and science of cartography. The lectures allow cadets and the instructor to discuss and explore new cartographic concepts, and lab exercises allow cadets to reinforce cartographic skills by effectively communicating complex spatial information through generalization techniques. The course introduces new online content to address the cognitive learning domain where mental skills translate into knowledge. The cognitive domain begins with the knowledge dimension where students learn basic cartographic concepts and eventually results in new geospatial products created in course exercises. Students then answer questions about their learning process in online surveys. The aim of the research is to determine if online, traditional, or a hybrid of the two was more effective in allowing students to learn cartographic generalization techniques. The goal is to assess student feedback, lab scores, and test scores to determine if these techniques enhance learning as well as retention of the subject matter.

Introduction

The proliferation of information technology has changed the education industry and how courses are both taught and delivered. With respect to teaching courses, educators have more options to present instruction material, specifically electronic material that can easily be posted or sent online. Improvement of technology and increased legitimacy of online learning within established universities has allowed for higher quality, 24/7 learning environments.[1] In terms of delivery, educators can teach in a traditional classroom setting enabled with the latest in information technology hardware and software, as well as present live webinars to students. This can present a number of challenges as instructors move content between mediums, as materials that may work in a traditional lecture may not resonate across an online connection.

Questions that can be immediately answered in an open classroom may not be received in the same context if there is a lag with the internet connectivity. Traditional classrooms often create a collaborative learning environment where discussion and dialogue can thrive, feedback is immediate, and peer-to- peer as well as instructor-to-student relationships are fostered.[2] It is advantageous when instructors learn to use teaching strategies that facilitate student understanding of both inquiry and content and move past teaching a course like cartography in an isolated or superficial manner.[3]

For cartography, the discipline of mapmaking once embedded in paper and ink, there is great promise in teaching online, as most modern mapmaking is created digitally and now moving more towards operating in a cloud environment. Cartographers understand that intuitions about map cognition can be developed more systematically with the application of scientific methods blended with advances in behavioral science, and the idea of cognitive cartography is more prevalent in the digital domain.[4] However, most cartography courses are taught in a traditional classroom using legacy content and delivery methods. Yet, it is expected that any student completing the cartography course can effectively communicate complex spatial information through generalization techniques. In the cognitive domain, knowledge is learned through understanding through the recognition of facts, patterns and concepts that develop into intellectual skills.[5] For cartography, it is essential to develop a baseline knowledge of the content before moving to analysis of existing products and the creation of new products. In my study, I wanted to determine if a major lesson objective - cartography related to generalization techniques - could be taught and learned as effectively in an online lecture as in a traditional classroom lecture. My hypothesis was there is no significant difference in learning effectiveness between online and face-to-face classes. I also wanted to determine if there were any specific reasons as to why one may be better than the other, or if a mix of both was a viable option.

Lecture Presentation

For the lecture, I presented a standard presentation used in previous semesters of the program's cartography course. I also adapted the same lecture into an online version which was presented in the same manner but without an instructor in front of the classroom. I designed the study based on previous research by the United States Department of Education that found instruction combining online and face-to-face elements had a larger advantage relative to purely face-to-face instruction than did purely online instruction.[6] The lesson explored the following generalization techniques: Simplification, Smoothing, Exaggeration, Aggregation, Collapse, Merging, Refinement, Enhancement, and Displacement. All students read the assigned homework from the course textbook, with one set of students reviewing the lecture on SharePoint and another set of students receiving a lecture face-to-face. All students then completed an associated computer lab exercise from SharePoint. Students were also required to answer an online survey with questions about the online and in-class lectures.

Cartographic Generalization Techniques	Effect To A Feature After A Cartographic Generalization Technique Is Performed And Displayed
Aggregation	Combines like features into one resulting symbol that best represents all of the features in a particular location
Collapse	Reduces area features (forests, cities) into representation as a point or line symbol as the scale of a product is reduced
Displacement	Moves a feature as optimally as possible from its true location when two or more features occupy the same space
Enhancement	Alters the physical size or shape of a feature’s symbol (normally an increase) to add emphasis for a specific purpose
Exaggeration	Amplifies or “zooms in” the size or shape of a feature to better visualize a specific aspect of the feature
Merging	Combines like line features into a single feature but preserves the characteristics of all features merged
Refinement	Thins out the smallest like features in an area to optimally retain the largest like features in their true locations
Simplification	Retains the least number of required data points necessary to properly represent a feature at a particular scale
Smoothing	Reduces edges/angles caused by prior digitization or conversions of features (result is more aesthetically pleasing)

Table 1: Cartographic Generalization Techniques

There are several reasons I focused on generalization techniques for this study. First, it is a major concept in the cartography course and already had lectures, exercises, and graded events for immediate use. Second, there is a considerable tradition in geography that explores how humans cognitively represent geographic-scale environments, and most geographic products have generalization techniques applied in the development process.[7] Third, in order to explore the cognitive domain with respect to learning effectiveness, geographic features created from generalization techniques could be linked to mental representations. Mental representations of the geographical world are dynamic, constructed for particular goals, and draw from multiple sources of seemingly disparate geographical information such as roads, landmarks, and cities which actually have spatial relationships.[8] Fourth, the interdisciplinary nature of the course allows for the integration of the cognitive domain with inquiry-based learning. A multidisciplinary effort is required to develop and validate cognitive models for geographical space, and cartography provides concepts and relations for geographical space.[9] Cartographers provide expertise in feature generalization, data classification and graphic symbolization, and with a strong grounding in geospatial information science can collaborate within the realm of social science.[10] Finally, using generalization techniques allows for inquiry learning, where students engage in knowledge building through lectures, lab exercises, a group project and student-crafted final projects. For example, a student who figures out how to use the software to conduct a smoothing technique may inform other students how it works and diagnosis is performed by the learners themselves. Moreover, the IT environment for the cartography course provides for the flexible exchange of information through a collaborative knowledge management forum (SharePoint) or chat/email functions.[11] The generalization techniques allow for the exploration of the cognitive domain in various learning environments.

Methodology

The study is designed to determine if online or traditional lectures are better for learning the techniques outlined in Table 1: Cartographic Generalization Techniques.[12] The objectives are to determine which methods are best for specific generalization techniques and to determine if students learn the techniques better online, in a traditional lecture, or a blend of both. According to U.S Department of Education studies, blends of online and face-to-face instruction, on average, had much stronger learning outcomes that did face-to-face instruction alone.[13] The goal is to use a series of online survey questions to determine if one method of delivery translates to better cartographic products. I instructed a cartography course last semester with 3 sections with over 30 students. I set out to determine what content was most effective online and what content was most effective face-to-face. This required an awareness of the complexity of digital competence, as it impacts the way in which teachers carry out and experience the pedagogical use of information communication and technology (ICT) based on their own digital competence.[14] This aspect of the study addressed my ability to identify, understand and implement relevant technology to increase learning effectiveness. This relates to the concept of *real affordance*, where teachers are able to recognize and utilize a technology's potential in an optimal way in teaching. The pedagogic implication is that teachers have reached a stage of recognizing the real affordances and can use their professional competence and expertise to address and overcome technical obstacles.[15]

Students enrolled in the cartography course were asked to complete survey questions regarding their experiences in learning generalization techniques. All responses from the surveys are anonymous and non-attributional. Students completed a lesson and practical exercise using the generalization techniques and were graded on their understanding of techniques in a lab exercise, a written partial review (mid-term), and a final course project. The survey addressed teaching methodologies employed and which are the most effective in learning the cartographic generalization techniques. The answers were assessed and compared to graded events to determine any trends. No interviews or any additional means of data collection were employed for this study.

Results

Learning effectiveness was essentially the same in an online environment as it was in a traditional classroom for learning to recognize the cartographic generalization techniques with respect to a lecture format. Overall, the grades in the cartography course were about 2.5% higher as compared to the previous semester, and the change in format could be a contributing factor to the increase. Students preferred a mix of lectures (online and classroom) depending on the performance objective. Hybrid courses result in superior student learning outcomes, not necessarily due to the format itself, but because students can spend additional time reviewing course material, specifically lectures.[16] Although United States Department of Education research found that learning outcomes for students in purely online courses and those for students in purely face-to-face conditions were statistically equivalent, the findings did not attempt to equate all the curriculum materials, aspects of pedagogy, and learning time.[17] The preferred approach (hybrid) does produce better learning effectiveness, but not strictly based on a mix of formats.

Shachar analyzed 125 qualifying studies and used learning outcome data from over 20,800 participating students to find that distance education is comparable to traditional instruction and in some cases outperforms traditional instruction.[18] The supporting evidence for this pro to online education is in the ability to review material. Students can often re-watch recorded lectures, repeat exercises, and take their time to master concepts.[19] In the survey, almost 44% of students indicated the main advantage to an online lecture is the ability to view it and review it at their own pace. Over 37% of students indicated that the online lecture is flexible, meaning it could be viewed at any time and from any location.

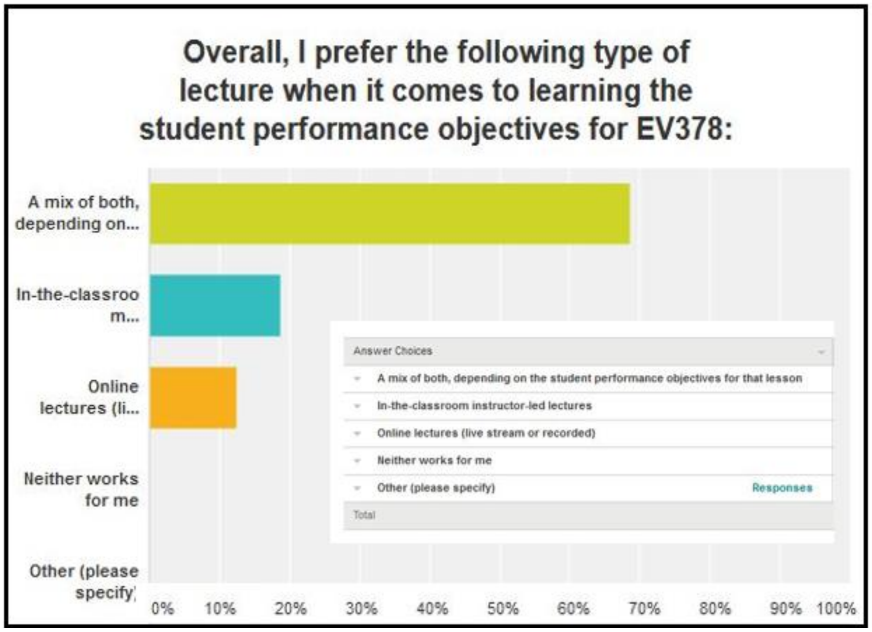

Figure 1: Lecture preference for learning student performance objectives

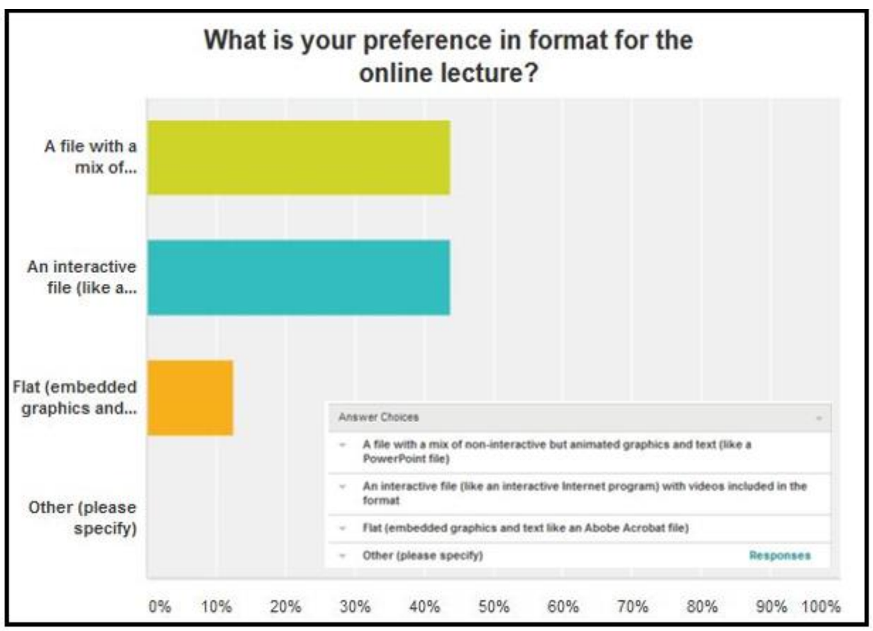

Figure 2: Online lecture format preference

However, the con to both online and traditional lectures can be technical problems, in that when problems using technology over the network arise, immediate technical support is often not available to the instructor.[20] This definitely impacts learning effectiveness, and for a digitally-based curriculum could significantly impact several aspects of the cartography course. For example, during the week of 10-14 October 2016, the United States Military Academy experienced a severe latency with its networks. This latency problem affected online exams, computer lab exercises, access to SharePoint and Blackboard, and required course directors and instructors to reorganize lab and exam schedules. Students could not access the wired and wireless networks, which limited the online collaborative environment and kept students from developing knowledge about cartographic concepts. Technology problems do impact online and traditional lectures, but the impact is actually more pronounced online, in that students in a traditional classroom would not have been impacted by a network outage. Besides the traditional form of acquiring geographic competence (paper maps and atlases) it is necessary to directly connect learning with digital competence using modern information and communication technologies.[21] Today, it is more likely that learning effectiveness from an online lecture is decreased in comparison to a traditional lecture with respect to technology problems, which limits access to information.

Other factors addressed in the study were speed of delivery by the lecturer, student motivation and grade expectation. Over 50% of the student responding to the survey indicated that the lecturer's presentation speed was about right. Over 25% indicated it was too slow, while about 20% thought it was too fast. No students indicated that the speed was much too fast or much too slow. For motivation, 50% of the students indicated that their motivation to view an online lecture instead of a traditional lecture made no difference. 30% had a higher motivation to watch an online lecture instead of attend a traditional lecture, and almost 20% had less motivation to watch an online lecture as compared to a traditional lecture. With respect to grades, over 55% felt that their written partial review (mid-term) grade would have been the same whether gaining the information from an online lecture or traditional lecture. Almost 19% felt their grade would be higher and 25% indicated that their grade would be lower, indicating these factors had little impact with respect to the lecture being received online or from an instructor in a classroom setting.

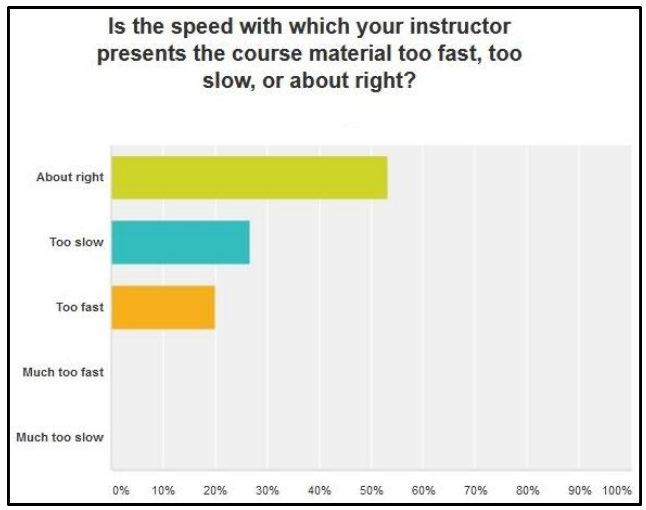

Figure 3: Instructor lecture - speed of delivery

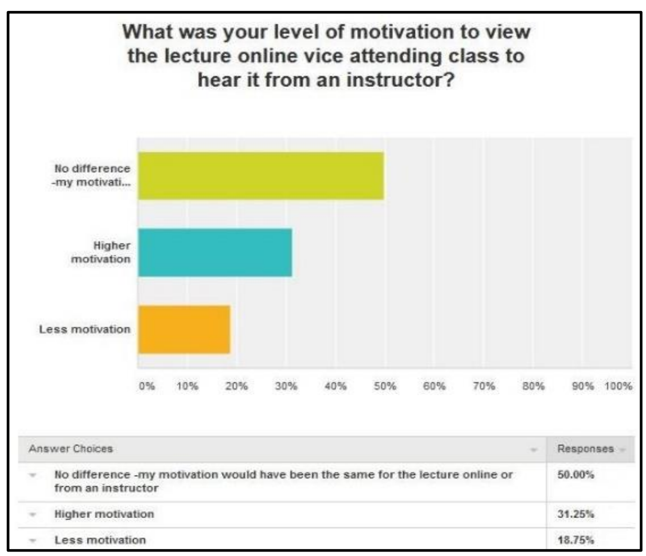

Figure 4: Instructor lecture - speed of delivery

Provided that the pedagogy is consistent, the manner in which the information is presented is more important to learning effectiveness than if it is from an online or traditional lecture. The *Multimedia Principle* asserts that instruction that incorporates words and graphics encourages learners to engage in active learning by making connections between verbal and pictorial representations.[22] For learning cartographic generalization techniques, learning a new process is generally achieved through generating, classifying, representing, linking and annotating elements of knowledge such as terrain features. This knowledge building approach tends to describe inquiry as an unpredictable, holistic process of creative development of ideas within a community of learners.[23] Students were asked which course objective contributed most to their interest, learning, and motivation. The course objective that resonated the most with students was Mapping, which allowed for the creation of thematic maps using geographic data to portray spatial relationships. This is the course objective in which most cartographic generalization techniques are learned and applied. From this objective, generalization techniques can be explored to determine how multimedia, enabled by technology and 3D animations, can increase learning effectiveness and be used optimally in both online and traditional formats.

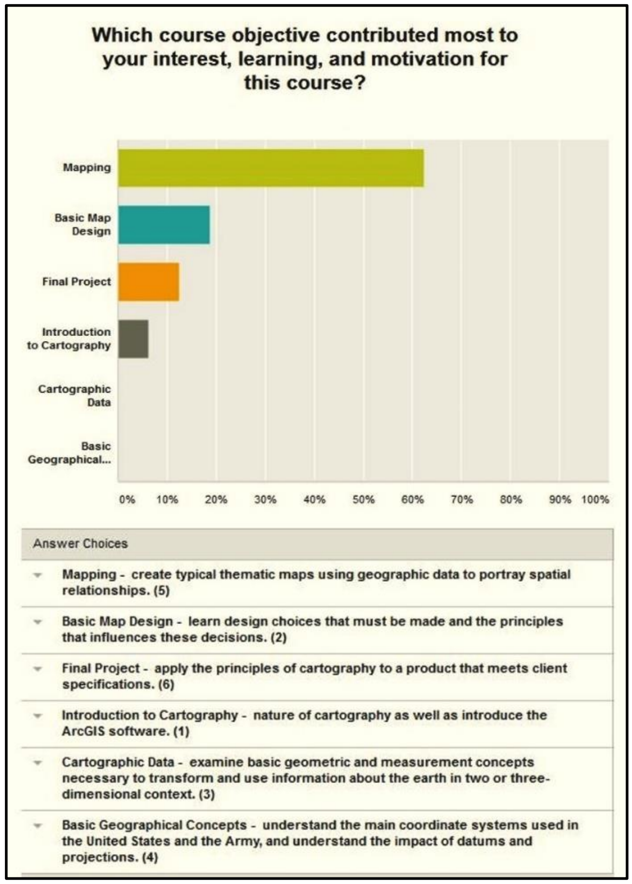

Figure 5: Course objective contributing the most to learning

In the survey, student were asked *"Which generalization technique did you find the most difficult to learn and use?"* Students indicated that *Merging* was the hardest to learn and that *Displacement* was the hardest to use. When asked "Which generalization technique did you find most useful in the course, as well as for you lab work and the final project?" most students selected *Simplification* closely followed by *Merging*. It was interesting to see that the hardest technique to learn was also prevalently used by many students for several projects. All generalization techniques were presented in the online lecture as well as the in-class lecture using similar graphics and grouped by categories similar to Table 1. It is possible that the maximum information with the least cognitive effort is achieved if categories map the perceived world structure as closely as possible.[24] This relates to cognition and categorization, where it is necessary when dealing with two dimensional (2D) representations to find a method to analyze similarity in the visual aspects of objects that are not dependent upon descriptions or names. The 2D representation of Merging is very similar to those of aggregation and displacement, which were tied for the next most difficult generalization techniques to learn. Without the definition listed in this graphic (which was used in the lectures), it is possible that students could confuse the techniques due to the similarity in the single color 2D representations of the features.

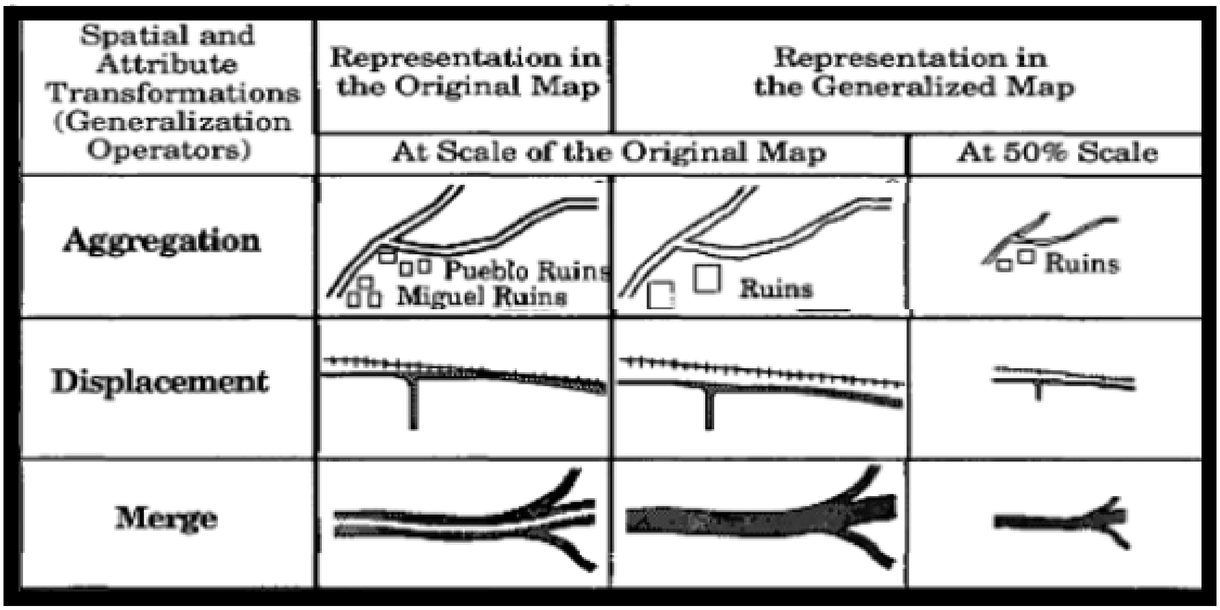

Figure 6: Most prevalent generalization techniques based on the online survey

Representations

Visual representations of geospatial data and concepts are indispensable the construction and enhancement of scientific knowledge.[25] Maps are 2D visual representations that also communicate information, thus the data and techniques used to create must be understood to optimize geospatial products. In a cognitive sense, geospatial visualization affects two areas: visual thinking and visual communication.   Moving seamlessly between 2D and 3D is the challenge for students in any learning environment, but technological advances in geospatial hardware and software make map animations much easier to create and modify.[26] Given the increasing role of geographic information systems, the need for comprehensible cartographic displays will increase, as will the need for developing educational programs to make map users (and map makers) more competent.[27] In a computer environment, maps are generally depicted as an abstract two-dimensional view with vision being the primary means of acquiring spatial knowledge.[28] Students are accustomed to learning in a 2D environment. The initial transition to 3D is difficult because the cognitive domain is typically engaged visually with books and computer screens, with supporting motor skills such as flipping pages or typing on a keyboard. For novice cartography students, there is also a potential for information overload when moving from a 2D to 3D environment.[29]

The use of new representation forms and interactive means to visualize geospatial data requires an understanding of the impact of the visual tools used for data exploration and knowledge construction.[30] Research indicates that people prefer 3D over 2D, but that performance goes down with 3D unless there is an understanding of the tools and methods used to create products.[31] Fabrikant and Lobben found that novice cartographers tend to prefer 3D over 2D representations and prefer more realistic, complex representations to simpler, more streamlined representations of the same construct.[32] Another study found that the perceived user understanding of the representations confirmed that a digital map created with ArcGIS and 3D-enabled features were generally well understand for all tasks.[33]

Novice cartographers who make widely disseminated maps with communication influence far beyond their foundation of training are not likely to make use of proper map generalization techniques. This is particularly true when they do not make use of basic cartographic principles in 2D or 3D.[34] In the absence of cartographic training, today's online technology does allow uneducated users to create "cartographic monstrosities" as geospatial products, which creates a need to formalize the knowledge necessary to support the complex design process.[35] A focus on the generalization techniques developed a knowledge base to alleviate such issues, and based on the results from the course grades, students with a higher order of understanding of the techniques tended to enjoy using ArcGIS software to create products. This required a focus on presenting the information in both 2D and 3D formats, and it did not really vary from being online or in the classroom lecture. For teaching mapping constraints and conflicts for a generalization technique like displacement, it is difficult to depict these items in a static, 2D format, but it can be explained in text or shown in a 3D animation much easier, and this can be accomplished online or in a traditional classroom environment.[36]

Conclusion

The most effective lecture with respect to learning effectiveness employs a hybrid format, where the content is adaptable to online and traditional environments, and an instructor is available to facilitate learning. There is little difference in whether or not the means of delivery is in a traditional classroom setting on an online source. The major factor affecting learning effectiveness is the content of the lecture, and for the cartographic generalization techniques, how that content is presented with respect to dimensionality. A live webinar could end up being an optimal hybrid format if the content is relevant and the information technology is stable enough to support the overall learning experience. It is also optimal if students have the ability to review the lecture after it is presented. To be effective, online lectures must not introduce information that will require additional explanation, but reinforces information that was obtained through reading the text as a homework assignment prior to viewing the lecture. Information with a mix of 2D and 3D content, specifically 3D animations, is optimal when 3D can provide the best representation of the feature or object.

Students new to cartography tend to see patterns in maps and readily interpret patterns ignoring the possibility that they might be the outcome of a chance statistical process generated by a computer algorithm.[37] For cartographers to create consistent and unbiased generalizations, they must first understand and determine which algorithm to use, then set the order to apply algorithms, and also input parameters with respect to the desired scale.[38] For objects that have a physical manifestation in the real world, shape is among the most important criteria for identification, and it is incumbent upon cartographers to understand how shapes in 2D and 3D affect recognition and thus representation when creating products using generalization techniques.[39] We still know little about the effectiveness of graphical displays for learning and knowledge exploration, but we know that both expert and non-expert cartographers prefer 3D animated displays to enhance realism of geospatial information.[40]

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