EFFECTIVENESS OF MENU-DRIVEN VS. SCRIPT-BASED GIS TUTORIAL SYSTEMS

Bin Li
Department of Geography
Central Michigan University
Mount Pleasant, MI 48858
USA
(517) 774-8886
bin.li@cmich.edu

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ABSTRACT

GIS tutorial systems are largely based on graphic user interface (GUI) consisting of windows, menus, and buttons. These menu-driven tutorials hide the complex details of the computational processes and eliminate the need to memorize command syntax, which supposedly enables students to focus on learning the concepts and developing problem-solving skills. Recent studies in cognitive psychology, however, revealed that the menu-driven tutorials for such subjects as mathematics and physics were not as effective as the traditional command-based tutorials. This paper reports the preliminary results of a project that evaluate the effectiveness of menu-driven tutorial systems as compared to script-based systems. We found that while both tutorial systems yielded similar overall test scores, script-based system showed improvement on learning conceptual materials.

INTRODUCTION

Geographic Information Systems, or GIS, is a subject that has undergone rapid development in recent years. GIS provides a conceptual framework and associated methodology that enable effective representations of spatial problems. It has become an important component in the curriculum of geography and related disciplines such as geology, biology, and operational research. Similar to other technically oriented subjects, GIS has increasingly been taught with tutorials for a particular software package. These tutorials are based on the graphic user interface (GUI) that mainly constitutes menus and buttons. Menu selection hence becomes the main mode of operations. It is the dominant form of GIS tutorials.

Personal observations and extensive research in cognitive psychology indicate that menu selection systems indeed may have significant drawbacks as learning mechanisms. Corbett, et al., for example, found that menu-driven data entry inhibits learning, compared to type-in code entry, even though students in the menu condition tend to like their tutor more (1991). Norman, on the other hand, detailed the general comparison of menu and command interface from the point of view of cognitive control and flow (1991). No such studies, however, have been conducted in the domain of geography and GIS.

GIS, in the form of computer software, is a computational abstraction of geographic space. It represents spatial objects as geometric entities and their relations as spatial functions. GIS attempts to model the real world processes as digital data and flow of computational instructions. Solving problems using GIS require the understanding of the entire computational process. The advent of graphic user interface, predominantly with menus and buttons, makes transparent the low level operations and supposedly allows the user to focus on problem solving instead of remembering command names and syntax. While this makes software easier to use, the high level abstraction by menus and buttons blocks the user from operational details. For students of GIS who need to understand the concepts and logics of a complex computational model, menu driven systems may actually serve as a cognitive obstacle. And yet, we don't know if this is the case and to what extent menu driven systems hinders the learning of GIS concepts and logics.

We believe a comparison between menu-driven and script-based GIS tutorials may shed some lights to the problem. Similar to command interface, script has well defined syntax. Each statement must be concise and each sequence must follow the operational logic. Compared with menu-driven interfaces, scripting provides a completely different learning experience. Would it be more effective to use script-based tutorials? This paper reports some of the preliminary findings from a comparison between two sets of ArcView GIS tutorials, with one menu-driven, the other script-based.

The following sections include a description on the methodology, case studies, and a discussion.

METHODOLOGY

The objective of the project is to find out if script-based tutorials are more effective than menu-driven ones in learning GIS at the introductory level. Below are some of the methodological considerations.

1. How should the tutorials be developed?
2. What procedures to follow to conduct the experiment?
3. How will the results be analyzed?

Development of tutorials

There are a number of considerations in developing the tutorials. We first have to make some assumptions about the background of the students. In this study, the only prerequisite for the course is an introductory cartography class. Programming experience is not required. The second consideration is the software platform to use. Such platform must be widely used and accommodate both menu-driven and scripting interfaces. The obvious choice is ESRI's ArcView GIS (ESRI, 2000). ArcView makes its entire application programming interface available through the scripting language Avenue. ArcView also has by far the most popular menu driven tutorial system, "Getting to Know ArcView GIS". The apparent approach, therefore, is to select the appropriate sections in the existing menu-driven tutorial then to develop the corresponding script versions.

Development of the tutorial follows these procedures:

- Formulating learning objectives
- Identifying learning topics
- Decomposing learning topics into tutorial topics
- Design and implementation
- Testing
- Documentation

Formulating learning objectives
The primary objective of the script-based system is to evaluate the effectiveness of alternative tutorial systems. It is foremost important to formulate the learning objectives, which will serve as the ultimate evaluation criteria. These objectives should be defined in three areas: conceptual learning, critical thinking, and operational skills. For example, the intended learning objectives (ILO) for the session on "Plane Coordinate Systems" are defined as following:

- Be able to describe the basic elements of plane coordinate systems.
- Understand the characteristics and applications of UTM and US State Plane Coordinate Systems.
- Be able to select or specify an appropriate plane coordinate system for a given region.

Identifying learning topics

The topics will cover the normal scope of Introduction to GIS. These are:

- Digital representations of spatial phenomena
  - Object representation
  - Database representation
  - Visual representation
- Selection
  - Attribute query, SQL
  - Spatial query, simple, complex
- Join
  - Relational join
  - Spatial join
  - Geometric overlay

Decomposing learning topics into tutorial topics

Each learning topic may contain several subtopics. For instance, object representation needs to deal with how the geometries as well as the attributes of point, line, and polygon are represented. In such case, two tutorials may be required. In addition, the prime reason to develop this system is to make a comparison with existing menu-selection systems. That target system is "Getting to Know ArcView GIS". The system contains some thirty chapters, each including several tutorials. It is important to carefully define the tutorial topics in the script system so that they correspond to the topics in the menu selection system. Each topic should be defined with reference to the concept and methods (functions) the students expected to learn.

Design and implementation

Avenue objects and requests are identified for each tutorial topic. Data sets identical to those used in the menu-driven tutorials will be used. Similar procedures are implemented.

Testing

Scripts for each tutorial topic are tested using sample data to identify bugs and errors.

Documentation

Comments will be added to the scripts. Descriptions of the tutorial are placed at the beginning, including the purpose, date, and the date of the script. Short comments will be inserted where explanation may be needed.

Conduct

The two tutorial systems were subsequently evaluated through a control experiment. Students were divided into two groups, A and B. Group A used the menu-driven system and B used the script-based tutorials. There were ten students in each of the group. To minimize academic bias, the grouping was done so that the mean GPA scores were approximately the same. With the group formed, the following activities were conducted for each module:

- Attend lecture (same for both groups).
- Complete tutorials (Group A used the ESRI tutorials, Group B used the script-based one).
- Review (separately for each group).
- Quiz (same questions for both groups).

The lecture introduces the concepts and corresponding software components. The software part includes both the graphic interface elements and the Avenue objects/requests. When working on the tutorials, Group A students would read the instruction then point-and-click through the steps. Group B students would have to type in the scripts, debug, and execute them. During the tutorial process, the instructor was available to provide feedbacks and answering questions.

The purpose of the review is to provide a summary on the operational matters, highlight the key processes, and make connections to the learning objectives for the session. This is also the time for students to ask questions related to the lecture and the tutorials.

After the review, a quiz follows. The quiz is the primary means to evaluating the learning effectiveness of the tutorials. The quizzes were designed based on a set of intended learning objectives (ILO). Quiz questions fall into three types, multiple choice, essay, and problem solving. Each quiz is graded on a 10-point scale.

Analysis of results

This study falls into the category of group comparison. There are numerous statistical methods for this type of analysis. T-test, for example, can be used to test for a statistically significant difference in the means of the test scores between the two groups. In addition to the comparison for average scores, we also test the differences for different types of questions, namely conceptual and problem solving. Furthermore, for a sample of this size, direct observation and qualitative methods should also play important roles. For instance, questions students asked during the tutorial and the quiz sessions can be recorded and summarized. (Students were allowed to ask questions even during the quiz session. It is the instructor's judgment on how the question should be answered so that the quiz reflects the objective measures of the student's capability.)

PRELIMINARY RESULTS

An experiment was conducted through a one-semester introductory GIS course. Twenty students were participated, resulting in ten for each group. The reference textbook is "Getting Started with Geographic Information Systems", third edition, by Keith Clarke. Students have access to the digital tutorial "Getting to Know ArcView GIS" and all related software documentations for ArcView.

Preliminary analysis reveals two findings:

- Statistical analysis shows no significant difference between the overall test scores of the two groups.
- Students using the script-based tutorials achieved higher scores on conceptual questions but had similar scores on problem solving.

We selected three topics as examples to illustrate the experiment.

1. Plane coordinate systems

ILOs:
- Be able to describe the basic elements of plane coordinate systems.
- Understand the characteristics and applications of UTM and US State Plane Coordinate Systems.
- Be able to select or specify an appropriate plane coordinate system for a given region.
Tutorial:
- Set the view, which contains the Michigan County boundaries, to the State Plane Coordinates, Michigan Southern Zone. (Modified from ESRI, Chapter 11, Setting a map projection).

Quiz:
1) Use SPC as an example to describe the basic elements of plane coordinate systems. (close book)
2) Specify a conformal projection for the Michigan Upper Peninsula.

Group A (script-based) outperformed B on both questions. For question (1), a common deduction for Group B students was from incomplete answers. This was expected because the menu-driven tutorial requires only selections of items from the drop-down menu. All projection parameters are set automatically. It generates no stimulus that may help re-enforce the lecture. On contrast, the script-based tutorial requires students type in the script, debug, and execute it. The script itself provides a structural and precise procedure for specifying a projection, which clearly supplement the lecture. The script also provides a general procedure for specifying a project, which helps Group A to achieve a higher score in question (2).

2. Thematic mapping

ILOs:
- Understand the basic concepts of Visual variables and cartographic symbolism
- Be able to perform a specific thematic mapping
- Be able to interpret a map generated with a particular classification method
- Be able to choose an appropriate type of classification method

Tutorials:
- ESRI Chapter 9, Classifying and Displaying Themes
  - Classifying features based on their attributes
  - Creating different legends
  - Using different classifications
- ESRI Chapter 10, Symbolizing Themes
  - Using markers and graduated symbols
  - Using pens, fills, and colors

Quiz:
1) What are the major visual variables? Which visual variables are more effective in representing different cartographic objects (i.e., point, line, polygon) and different types of measurements (i.e., quantitative, qualitative)?
2) What are the major classification methods for quantitative attributes?
3) Create a map that shows the geographic distribution of population in Michigan, US.

The overall scores were not significantly different between the two groups. For specific questions, however, there were some notable differences. Group A (script-based) showed better performance on question (2) while Group B outperformed in question (3). We have not come to a full understanding as to what attributed to such difference. At this point, we can offer some speculations. During the tutorial session, Group A students had to write the Avenue statement that specifies the classification method, which is similar to the following:

```legendl.VectorLayer.Alternate aTheme, aString, numClasses```

Students in this group were reminded to review the on-line documentations on the related software objects and the requests, when encountered problems. Many ended up studying the on-line documents, which gives excellent discussions on classification. For students in Group B, the menu-driven tutorial presents no challenge what so ever hence lacked the opportunity to actively discover supplemental information.

For question (3), students had two obvious approaches, i.e., a choropleth map or a dot density map. Most students were unsure which one to use before hand so they began experimenting with both methods. This gave Group B a greater advantage. For Group A, some students were unable to complete the task within the quiz period due to the complexity of the programming process for legend construction.

3. Selection

ILOs:
- Understand relational and logical operations.
- Understand the common types of spatial relationships.
- Be able to solve application problems using a combination of attribute and spatial selections.

Tutorials:
- ESRI 17 (proximity and adjacency)
- ESRI 18 (containment)
- ESRI 19 (intersected)

Quiz:
1) What are the common spatial relationship types between geographic features (vector)?
2) Three application problems (proximity and adjacency, containment, intersected)

Group A students had no problem at all with question (1) because all they need to do is find the on-line help for "FtaRelTypeEnum" that lists all the spatial relationship types supported by ArcView. Group B students, however, were mostly familiar with the "Select by theme" dialog which shows the relationship types only appropriate for the corresponding themes. They did not have a clear view on the entire set of spatial relationships. Therefore, answers from Group B were mostly incomplete.

Results for question (2) did not show significant difference between the two groups. There were some interesting observations. Students in Group A seemed to know what to do. The main problem was debugging the script which was modified from the tutorial. They needed to make all the necessary changes to fit the current data, which requires the student to understand the scripts. The students had limited experience with programming therefore they got frustrated easily, which had negative impact on the resulting scores. For Group B, the problem was just the opposite. Students were not sure where to begin. They started trial-and-error. Since the choices were limited, students with a clear strategy were able to complete the task within a short period of time. Subtle operational details, however, caused errors in their answers. A common mistake was selecting the wrong "theme". Regardless how many time the instructor highlighted the importance of activate the theme to be selected, there were always substantial number of students making the same mistake again and again.

CONCLUSION

Preliminary findings from this experiment were not conclusive. It seems clear that the script-based tutorials help improving conceptual understanding but may not be much more effective than the menu-driven tutorial in learning problem solving. Below are some additional thoughts.

1. It is obvious that the script-based approach requires a longer learning curve. The learning outcome therefore may need to be assessed in an extended period of time and through subsequent courses.
2. It is also obvious we need to find out if a hybrid approach, which combines script-based and menu-driven tutorials, would perform better.
3. While software scripts are similar to each other, graphic user interfaces can be substantially different. The effectiveness of the GUI design could be an important factor influencing learning hence needs to be accounted for. We need to understand the inherent drawbacks of the menu-driven tutorial system, which may be overcome through inclusion or substitution of script-based systems.

4. Finally, more studies need to be conducted. Different methodologies should be used. For instance, qualitative methods such as focus group procedures may well provide additional insight on the subject.

REFERENCES


ESRI, 2000, Getting to Know ArcView GIS, Redland, California.


