THE CONVERGENCE OF TEXT AND GRAPHICS IN AN ONLINE LEARNING ENVIRONMENT: A CASE STUDY IN ECONOMICS

Deborah Ingram
Centre for the Advancement of Teaching and Learning
The University of Western Australia, Australia
dingram@catl.uwa.edu.au

Eileen Thompson & MoonJoong Tcha
Faculty of Economics and Commerce, Education and Law
The University of Western Australia, Australia
eileen.thompson@uwa.edu.au
mtcha@ecel.uwa.edu.au

Abstract

While much visually oriented teaching material that uses the new technologies is being developed, there is little understanding or research into the demands such material makes on students' information processing. This paper outlines an innovative approach to teaching complex economic models that incorporates the convergence of text and graphics in instructional material in an online learning environment. The Interactive International Trade (IIT) program is designed to improve the effectiveness of teaching and learning by the effective, efficient and innovative use of graphics as well as equations and text in teaching material on the World Wide Web.

The paper describes the implementation and initial evaluation of this approach to teaching economics. It proposes that the technical capacity to be able to generate dynamic graphics in teaching material needs to be distinguished from the issue of whether or not the generation of dynamic graphics is likely to have desirable perceptual and cognitive consequences for students. The findings will give us some indication of how this type of instructional material is impacting on student learning, identify ways it can be improved and provide some guidelines for the future development of similar material to support student learning.

Keywords

instructional graphics, teaching complex economic models, online learning

Introduction

The particular attributes of an online learning environment potentially extend the didactic possibilities for teachers by providing them with powerful new ways to represent knowledge (Schnotz, 1999). Different information processing demands will be placed on learners as they interpret these different ways of representing knowledge. The cognitive demands of integrating text and graphics appear to differ according to whether the graphic is static or dynamic. Teachers need to ask, "Will these new ways of representing knowledge improve the learning experience of the learner?" and "What needs to be done to support the learner in those cases where additional processing demands are made of the learner?"

The Interactive International Trade (IIT) program was developed by MoonJoong Tcha of The University of Western Australia, for the Department of Economics, with financial support from a Teaching and Learning Initiative Grant. The program is used for three units at present: Asia in the World Economy (400.203), International Trade (400.235) and Topics in International Economics (400.450). The IIT program is an interactive computer program, written in Java and available on the Internet as complementary teaching material for these units (see International Trade, Online).

The development of the IIT program raises many questions. What impact is the IIT program having on students' understanding? Is the IIT program enabling or preventing students in performing relevant cognitive processes? The aim of this paper is to describe the IIT program, to consider the pedagogical and technological aspects of the program and to explain the evaluation process that is currently being undertaken.

The Use of Graphics in the Study of Economics

Economics is the study of human behaviour as a relationship between human wants and the limited resources to satisfy those wants (Miller & Shade, 1995). Economists use models to assist them to understand the abstract features and relationships of the complex economic world. The models used by economists are simplified representations of real world situations. Because the real world situation can be too complicated to include every feature, economists restrict themselves to using the most important features of the real world situation in order to analyse, understand and explain the most important relationships. In order to simplify the real world situation, economists make certain assumptions. The fewer assumptions economists have to make, the more realistic and true to the real world situation the model will be. Ideally a model will show the most important relationships while staying near to the real world situation. Models can be developed as equations, as written descriptions or as diagrams (Taylor, Moosa & Cowling, 2000; Miller & Shade, 1995).

Such an explanation of economic models does not take into account the educational dimensions that need to be considered when developing and using these models. The process of simplifying information into graphic forms can often mean removing information from the graphic that is already in the subject expert's head but is not yet in the novice's head. What is easy for the subject expert to "see" is not as easily seen by the novice. The assumptions the subject experts make are not necessarily apparent to a novice. The subject expert is able to supply missing details and information from a well developed knowledge base and is able to then contextually embed the information supplied by the graphic to build up a coherent mental structure. What the subject expert sees as a graphically simple and economic representation of information is, in fact, a professionally sophisticated representation of information that depends on a well developed knowledge base in the reader. A novice often does not have a sufficiently well developed knowledge base to enable them to build a coherent mental structure of the information embedded in the graphic.

Hartley (1994) classifies signs as either iconic or digital. Iconic signs, such as photographs, illustrations or diagrams, resemble their referent in some way. Digital signs, such as words or numbers, do not need to resemble their referent in any way. In such cases as texts with diagrams, illustrations with captions and symbols with explanatory labels, both iconic and digital sign systems are combined. This distinction seems somewhat simplistic when applied to economic models. While such models may be simplified representations of real world situations, they are dealing with abstract features and relationships of the complex economic world. Lowe (1998) distinguishes levels in representations, or genres, which range from concrete, realistic and literal, such as photographs, through to abstract, such as words and diagrams, and levels in referents, or subject matter, which range from those that are accessible and physical to the invisible and not physical. In economic models, the referent is a real world, complex economic situation. It is invisible and not accessible. The representations are highly abstract. Taylor et al., (2000) state that "economic models can be described with words, with numerical tables, with graphs or with algebra" (p. 16) and claim that "developing an eye for economics as represented in graphs is easier than developing a nose for numbers in tables" (p. 25).

A graph can be defined as "a drawing that presents the changes of and the relationship between two or more things through the use of the visual elements and various forms of visual notation" (Saunders, 1994; p. 185). They are "designed to suggest inferences, generalisations, and evaluative interpretation" in order to help learners gain meaning (Knupfer, 1994; p. 214), but there can often be a contradiction between the author's intentions of helping learners and the actual effect of their efforts on learners.

When 'reading' text or graphics for information, learners need to have knowledge about where to look for the information they need, knowledge about what the elements of the medium are, knowledge about the sequence to follow when reading the medium and knowledge about how to connect the information in each medium.

Conventional wisdom would say that graphics help to explain text, but the reverse is also true. Graphs are not necessarily self explanatory. They need text to explain them. In an economic model, such as the ones in the IIT program, a subject expert may be able to hazard a guess about what is represented but a novice would be struggling to even begin.

Another aspect that also needs to be considered when text and graphs are combined is the cognitive processing load for a learner. Both text and graph compete for the limited attention and processing resources of the learner. The high processing demands of the graph may be better supported by aural (spoken text) rather than visual (written text) means, thus capitalising on two perceptual channels (aural and visual) rather than just the one (visual).

The cognitive demands of integrating text and graphics appear to differ according to whether the graphic is static or dynamic. The willingness of learners to study graphics improves when the graphics are animated but their understanding of the processes illustrated seems to be impaired or distorted (Wright, Milroy & Lickorish, 1999). In some circumstances, the processing demands of dynamic graphics have been found to have a negative effect on learning (Lowe, 1999). Dynamic graphics can prevent learners from performing relevant cognitive processes and so may not be beneficial for learning (Schnotz, Böckheler & Grzondziel, 1999).

Processing Demands of Graphs

The eye is like "an information gathering probe for the brain" (Lowe, 1998). Light reflected or emitted from an object passes through the eye to the retina and this activates an electrical impulse to the brain that is interpreted as a representation of the object. While the essential structural features of the object are selectively captured, the subsequent "image in the brain" is not identical to the viewed object.

The very start of processing (the pre-attentive phase) is likely to be dealing with gaining a global or holistic impression of the graph (Lowe, 1998). Broad scale organisational influences on perception will work to separate the visual information so that the learner can discriminate between the individual parts. Gestalt effects on perception will work to impose structure on the visual information. Because human viewing is highly selective, visual signals that differ substantially from the rest of the visual field, anything unusual, unexpected or in contrast with the surroundings will draw the learner's attention. This needs to be considered when using animation in an online learning environment as it could distract the learner leading to an inappropriate use of the learner's finite cognitive resources.

Like text, numbers and pictures, a graph is a form of information. The learner needs to use two types of information to interpret a graph: their own prior knowledge and the information supplied by the graph. The learner needs to draw on their prior knowledge of the subject as well as their prior knowledge of the elements of a graph. During viewing, the elements of the graph need to be identified and interpreted. The learner needs to reverse the "transformation" from the real world economic situation to the graph. Relationships and changes depicted in the graph need to be identified and converted to the real world economic situation depicted. They need to flesh out the

representation of the real world economic situation by relating it to what they already know. How well this is done is influenced by the learner's knowledge of graphs, the learner's knowledge of the subject and the learner's task. Aspects that are obvious to a subject expert may be missed by novices who lack knowledge of the subject area or who lack knowledge about how to read graphs.

Graphs can be explored in a range of different ways depending on the learner's task, needs, knowledge and interest. As hypotheses about the content of the graph are built up and tested by the learner, the learner's viewing behaviour and purpose will change. Attention may be confined to certain aspects of the graph that the learner considers relevant or compelling while other aspects are ignored.

For learners to 'read' a graph, they need to know where to look, what the elements of the graph are, what sequence to follow and how to connect the information. An online learning environment can provide the means to deliver both static and dynamic graphs. Perceptual and cognitive processing demands need to be considered when developing graphs for an online learning environment. Technical constraints also need to be considered.

Development of the Interactive International Trade Program

The students enrolled in the three economics units where the IIT program is currently used have various backgrounds. Some are very good at economics while others are doing the unit because it is required for their degree. Some are international students with English as a second language.

The information in these units contains very complex models, possibly the most complicated in economics. Most economic models look at economic factors in one country. In International Trade, the model has to be understood for one country, generalised to other countries and then the interaction between the two or more countries has to be understood. The static graphs in the textbooks that attempt to explain these are very complicated. The lecturer uses PowerPoint slides or overhead transparencies in classes but has found that students just copy his graphs and then cannot remember what all the lines are about!

The lecturer believes it is important for students to "build up the graphs themselves" (personal communication, March 21, 2001). He reflected on what would be the best way to explain the material and considered using maths, graphs or just talking. He thought that graphs were better because students did not like maths and he, himself, preferred graphs in order to understand the concepts. He approached two computer scientists (one a student) and, with the assistance of grants and funds from the university, taught them economics (both introductory and international). They then wrote the program. The first stage, *Basic models of international trade,* and the second stage, *Trade policies and welfare analysis*, have been completed and have been available for students to use for two semesters. A third stage is to be developed once the evaluation of the first two stages is completed. The lecturer considers the main benefit for his students as the ability to access the material "whenever, wherever, without cost".

Description of the Interactive International Trade Program

The IIT program has two parts:
- Basic models of international trade;
- Trade policies and welfare analysis.

The material is presented in two versions:
- A non-interactive version – the preferred option for printing. This version has been supplied for those students who have browsers that do not support Java;
- An interactive version – Java applets have been used for interactivity.

In the both versions, text and graphs have been combined in order to describe complex abstract concepts.

Analysis of the Interactive International Trade Program

Does the IIT program improve the learning experience of the learner? What processing demands do the graphs in the IIT program make on learners? What needs to be done to support the learner in those cases where additional processing demands are made of the learner? These are just some of the questions to be addressed in the analysis and evaluation phases of the program.

Knowledge Needed

Knowing where to look and knowing what the elements are

Key elements of the graphs in the IIT program are clearly defined. Shape, size and color have been used to clearly differentiate the key elements in the graphs. Labels have not been used extensively on the graphs and the graphs cannot "stand alone". They make sense only when considered along with the accompanying text.

Both text and graph provide complementary information – neither can stand alone. The student needs to extract the best information from each source and then mentally combine these two sets of information into one coherent set. Attempts have been made to make this as easy as possible for the student. The text and graph have been kept as close as possible. Symbols used in the graph are explained in the text thus reducing the need to cover the graph in labels.

Knowing the sequence to follow and knowing how to connect information

Reading the graph at an internal level (within the graph) is guided by two strategies: the sequential order of the graphs and accompanying text and the embedding of more detailed information in the graph to be activated when the learner has processed the information already covered.

The relative importance of information central to the theme is built up gradually by explaining successive graphs. For example, The General Equilibrium Model – Autarky (International Trade, Online) section has four graphs. The first graph lays the foundational central information required to understand successive graphs. Some of the detail of this graph is no longer required so has been removed for the second graph and more pertinent information added. This is built on in the following graph. In the fourth graph, the information built up in the previous three graphs is generalised to a similar situation.

Students need to be able to construct meaning from all the layers of information that are embedded in the graph "from the global level right down to the details" (Lowe, 1997; p. 24). This requires the flexibility, on the part of the learner, to move between levels and to develop an understanding of the inter-relationships between the different levels. The use of sequential graphs explicitly indicates the various levels in the final graph and the use of animation explicitly reveals the process represented by the graph. In this way, attempts have been made to support the development of a rich understanding of the information represented by the graphs.

In the second stage, *Trade policies and welfare analysis*, for example in *Quotas* or *Export subsidy – large economy*, the interactive buttons animate lines, points and blocks of colour. These are used to reveal the varying levels of information (axis, shape, space, meaning) thus highlighting the relations between the ideas and the area to be focused on as well as the sequence in which to read the graph. One aspect of the visual information that we are daily bombarded with is that of colour and the creator has used colour in these graphs. Colour is considered to have a profound impact on us, affecting us psychologically as well as being imbued with symbolic meaning (e.g., red for danger) (Chiazzari, 1998).

Information processing
Students need to pay attention to, or have their attention caught by, particular parts of the graph in order to develop their understanding of the subject matter. The author has capitalised on the animation capability of the online environment to direct the students' attention to the important parts of the graph and to illustrate the process that needs to be understood. Critical features have been highlighted by the use of colour and critical processes by the use of animation (see, for example, International Trade. General Equilibrium section – Autarky , Online). In the interactive version, in order to increase the instructional effectiveness of the graphics, deeper levels of visual information are activated when the learner clicks on a button embedded in the text. Arrows appear indicating the increase or decrease and a line that moves to indicate what needs to happen is activated, then disappears. This occurs automatically in the non-interactive version. In the interactive version, the learner has control over the timing of when the animation is activated and how often the animation is activated. The graph is automatically animated in the non-interactive version. This may make the material harder to process.

In Quotas – Free Trade (International Trade, Online) eight items of information are embedded in the one graph online. Would a series of graphs be more effective? Would comparing graphs side by side (possible in a print environment) be more effective than the cumulative build up that is presented in the dynamic form online? These are some of the questions that will be addressed in the evaluation of the IIT program.

Research Methodology and Data Collection

The IIT program was designed to enable students through self-paced online activities to build up their understanding of complex models associated with international trade. The program was also developed to free up lecture time for the development and clarification of key ideas and concepts. The program was not a compulsory part of their study, but the lecturer has strongly encouraged students to use it to enhance their understanding.

Some evidence of the degree to which the IIT program is successful in improving teaching and learning is being sought through the evaluation process that is currently in progress. To help ensure the evaluation design does not unduly influence the reported outcomes, a mixed approach to data production and analysis has been adopted, with both qualitative and quantitative information being obtained in the evaluation process (Reeves, 1997).

Initially, the impetus for the development of the IIT program came from the lecturer after his reflections of teaching complex economic models identified a need for a more effective approach. The inadequacy of traditional approaches (overhead transparencies in a large group lecture) and the potential offered by utilization of computer-based technology enabled the consideration of alternative methods of instruction. These initial concerns held by the lecturer are an important component of the evaluation data and were integrated into the design of the program and the implementation phase of this teaching initiative.

Information about the characteristics of the students enrolled in International Trade in first semester 2001 and their experiences using the IIT program have been obtained from two surveys. The first survey was administered early in the semester and contained questions about computer usage and access, and basic demographic details such as age and gender. The second survey was administered towards the end of semester and was a much more substantial document. In addition to repeating some of the earlier questions, the survey was designed to obtain detailed information about students' experiences using the IIT program (e.g., how often they accessed it, the ease with which they were able to navigate the site, their purpose in visiting the site). Additional data has also been obtained from a small number of structured interviews with students enrolled in the unit that semester. The content of the interviews and what questions to ask was guided by previous research (Patton, 1990). A variety of question types were asked including experience/behaviour questions, opinion/value questions, feeling questions and knowledge questions.

The evaluation process has also taken into account feedback received from other educational specialists including peers with some relevant subject knowledge and from colleagues with a multimedia or instructional design background. Data was obtained using an evaluation tool based on the work of Reeves (1997) that had been modified to suit the IIT program. This tool contained questions about both pedagogical and interface issues.

Preliminary Feedback

In the first trial of the IIT program the Students Perceptions of Teaching (SPOT) evaluations (independent student evaluation of the unit) were used to provide an initial evaluation of the program. The SPOT included two questions about the web site. In response to the question *Have you visited the web site?* 52 students responded "yes" (57%), 19 responded "no" (21%) and 20 gave no response (22%). The next question asked was *If visited, was it helpful?* 5 students responded "neutral" (10%), 18 responded "agree" (35%) and 29 students responded "strongly agree" (55%).

In the second trial (semester 1, 2001) and in response to the question *On average how often during the semester have you accessed the IIT web site?* 4 students (5%) indicated they accessed the site 2-4 times per week, 23 students (32%) accessed it weekly and a further 25 students (34%) accessed the site monthly. 20 students (27%) responded that they had not accessed the IIT web site largely because they either did not know about it or they did not see it as an integral component of the unit. Others responded they intended to use the IIT program as part of their preparation for the end of semester examinations.

The lecturer has had considerable international interest in the program and has had requests for permission to translate the material for use by non-English speaking students from other academics. He has also had commercial interest shown in the work, but is committed to making the material available as freely as possible. The lecturer has also had comments about the fact that he has not included animation (as in cartoons) or sound (music). He considers it more important at this stage to complete the program than to add in the "extras". He would like to be able to include self-checking quizzes at the end and to incorporate appropriate sound.

Conclusion

The IIT program contains very complex models, possibly the most complicated in economics. Because an online learning environment can provide the means to deliver dynamic graphs, the lecturer chose to use this format to provide his students with supplementary material to assist them in their study of these models. This paper has described the IIT program and discussed the pedagogical and technological aspects of the program. The potential demands on students' information processing ability have also been discussed. The evaluation of this program will provide further understanding of the demands such material makes on students' information processing and provide insight for the future development of similar material to support student learning.

References

Chiazzari, S. (1998). *The complete book of colour*. Ringwood, Victoria, Australia: Element Books.

Hartley, J. (1994). *Designing instructional text* (3rd ed.). London: Kogan Page. International Trade. [Online]. Available: http://www.firststep.com.au/econ [September 2001]. International Trade. *General Equilibrium Model - Autarky* [Online]. Available http://www.firststep.com.au/econ/GEModel1.html [September 2001]. International Trade. *Quotas – Free Trade.* [Online]. Available http://www.firststep.com.au/econ/quotas.html [September 2001].

Knupfer, N.N. (1994). Computers and visual learning. In D. M. Moore & F. M. Dwyer (Eds.), *Visual literacy: A spectrum of learning* (pp. 209–234). Englewood Cliffs, New Jersey: Educational Technology Publications.

Lowe, R. (1997). *How much are pictures worth?* Workshop Presentation, Uniserve Workshop Proceedings.

Lowe, R.K. (1998). *Education 387 (Visual Learning) Reader*. Bentley, Western Australia: Curtin University of Technology.

Lowe, R.K. (1999). Extracting information from an animation during complex visual learning. *European Journal of Psychology of Education, 14*(2), 225–244.

Miller, R.J., & Shade, E.D. (1995). *Foundations of economics* (4th ed.). Melbourne, Australia: Longman.

Patton, M.Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). California: Sage.

Reeves, T.C. (1997). Established and emerging evaluation paradigms for instructional design. In C. R. Dills & A. J. Romiszowski (Eds.), *Instructional development paradigms* (pp. 163-178). Englewood Cliffs, New Jersey: Educational Technology Publications.

Saunders, A.C. (1994). Graphics and how they communicate. In D. M. Moore & F. M. Dwyer (Eds.), *Visual literacy: A spectrum of learning* (pp. 183 – 192). Englewood Cliffs, New Jersey: Educational Technology Publications.

Schnotz, W. (1999). Introduction. *European Journal of Psychology of Education, 14*(2), 163–165.

Schnotz, W., Böckheler, J., & Grzondziel, H. (1999). Individual and co-operative learning with interactive animated pictures. *European Journal of Psychology of Education, 14*(2), 245–265.

Taylor, J.B., Moosa, I., & Cowling, B. (2000). *Microeconomics* (Australian Edition). Brisbane, Australia: John Wiley and Sons Australia, Ltd.

Wright, P., Milroy, R., & Lickorish, A. (1999). Static and animated graphics in learning from interactive texts. *European Journal of Psychology of Education, 14*(2), 203–224.