Challenges of Supporting Specialized Diagramming in the e-Learning Environment

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Short Research Paper

Abstract - *Many disciplines require learners to create diagrams that are standard to the practice. Diagramming, or drawing, has many benefits in learning and helps prepare students for diagramming in professional practice. Online e-learning, in which the student and teacher are not collocated, compounds the challenge of learning specialized diagramming. Recent developments in web-based diagramming tools are changing the landscape by reducing some barriers to diagramming in the e-learning environment. Cloud computing and Software-as-a-Service (SaaS) are the major enablers of web-based tools. This paper provides background on specialized diagramming in both learning and in professional practice, examines problems with traditional diagramming tools, explores the benefits of emerging web-based diagramming tools and argues the need for further research regarding specialized diagramming in the e-learning context.*

Keywords: Diagramming, web-based software, software-as-a-service (SaaS), e-learning

1 Introduction

Many science, technology, engineering, and mathematics (STEM) fields require specialized diagramming to analyze problems and learn to apply concepts. Examples of specialized diagrams include process flow, chemical structure, electronic circuit, and systems analysis diagrams. Students need both exposure to the diagrams and practice using the diagrams. In the face-to-face classroom setting it is easier to work problems on a whiteboard or review student work on paper. In the e-learning environment obtaining experience with diagramming and submitting practice for feedback becomes more challenging.

1.1 Diagramming

Ainsworth, Prain, and Tytler [1] write about the importance of drawing in order to learn science. Drawing can enhance engagement, deepen understanding, and support learning to reason. Drawing can show conceptual understanding, communicate complex ideas, and can be transformative in developing new inferences.

Both Lane [2] and Ainsworth, Prain, and Tytler [1] emphasize the importance of going beyond learning the rules for constructing diagrams to using diagrams to think about problems and solutions. In this way the emphasis is placed on the application of the diagramming technique to solve new problems. A diagramming tool that supports activities over artifact introduces the engagement that activity-based learning engenders [3]. Encouraging students to make multiple representations or models of problems and proposed solutions can enhance conceptual understanding [4].

Model-based reasoning involves analysis and problem solving. Developing models entails selection, organization, and integration of ideas. The process of building external models also leads to the development of internal models, an important educational goal [5].

Learners need experience using the diagrams and practice preparing professional quality versions of the diagrams. Benefits of experience include: practice applying diagramming techniques versus reading diagrams; experience using diagrams that are used in professional practice; and communicating more clearly with others than with rough sketches. Using a tool to generate diagrams that are professional in appearance can boost student confidence and contribute to a polished portfolio for future use.

1.2 Diagramming in professional practice

The old adage that a picture is worth a thousand words suggests the fundamental merit of using specialized diagrams. Diagrams can represent complex systems in ways that are difficult to do in written narrative [2]. Diagramming is a means of communication that conveys abstract representation of real work problems. They can transcend the confusion and ambiguity of written descriptions. Using diagrams is an important communication skill and also valuable in learning. Students may not be aware of the value of diagrams in communicating ideas and do not use diagrams as effectively in communication [6].

Many aspects of diagramming are fundamental to developing professional expertise [1]. Yet there is very little research on drawing in practice [7] and specifically in software development. However, Lane [2] presents four categories for diagrams used in both learning and professional practice: analogue, schematic, symbolic, and conceptual representations. Each category encompasses diagrams that represent real work problems.

A of survey found that 100% of the respondents found diagrams to be essential or helpful. Drilling down, 73% of respondents considered diagrams essential to any systems study with the remaining 27% reporting that diagrams are helpful [2]. It is noteworthy that the vast majority of respondents in this study (63%) were practitioners. Given the dominance of practitioners the study findings it can be inferred that diagramming is central the work process in practice. The rational about the benefit of using diagrams in system studies is shown in Table 1. Yet, in an investigation into the use of diagramming by distributed developers of the operating system Ubuntu, even professionals experience barriers to using diagrams in a distributed environment including lack of compatibility across tools [8].

Table 1. Reasons given for using diagrams in systems studies [2].

Reason	Percentage Reporting the Reason
Provides clarity of thought or understanding	31
Shows relationships, boundaries, and links	31
Showed whole situation	22
Helped communication	17
Quicker to produce and read	12
Sharing or exchanging knowledge and ideas	12
Helping with reflection and discussion	10
Making assumptions explicit	8
Sharing own thinking	4

2 Diagramming Software

A learning management system (LMS) is software that provides the mechanism for interaction in online and distance education. LMS are designed for general purpose use rather than for a specific discipline [3] and hence lack the flexibility to support specialized needs [4].

Some LMS can integrate other software systems into the LMS via software called plugins. The plugins related to computer science tend to have a narrow focus on one diagramming model such as Unified Modeling Language (UML) or dynamic visualizations rather than providing a broad range of drawing tools.

Learning management systems (LMS), frequently used to implement e-learning, may have a digital whiteboard feature or lack diagramming tools altogether [4]. In either case it is difficult to support modeling and diagramming needs in e-learning. The whiteboards in LMS require freehand drawing with a mouse, stylus, or finger making students self-conscious about drawing skills and making it difficult to generate professional diagrams.

Going outside the limits of a LMS using traditional software introduces a number of additional barriers to the adoption and application of specialized diagramming in e-learning.

Traditional specialized diagramming tools suffer from a variety of potential problems or barriers to adoption. Traditionally, specialized diagramming tools required the download and installation of software on the user's computer and presented users with several potential barriers to adoption. Some users may simply not be comfortable downloading and installing software. User computing platform, operating system or specifications may pose a barrier in that the user's platform (e.g. PC versus Apple) or operating system, such as Android, is not supported. Further the user's computer may have insufficient resources to easily run the diagramming software.

A single class of students may have many variations in their computing systems. Installation raises the challenge of properly configuring the software for the myriad of systems. This is a particularly challenging problem in e-learning. It can be very difficult for the instructor to provide sufficient configuration support particularly in a distance environment. Experience with configuration problems can delay their ability to carry out course assignments. The inability for a student to begin their assignments is debilitating for courses delivered in an accelerated format such as eight-weeks.

Traditional diagramming software is sometimes offered as freeware. More common is software that requires a purchase after a trial period. Sometimes the output from trial software is overlaid by a watermark bearing the vendor's logo. Prices for specialized diagramming may be prohibitive for students, ranging from educational discount rates (e.g. US$69) to hundreds of dollars US. In some cases the diagramming software serves a specific niche but not the range of diagrams needed for a given course.

2.1 Benefits of Web-based Diagramming Tools

Many of the problems may be solved by using web-based diagramming tools. Rather than installing software locally, the vendor hosts the software on their own servers. This is a fundamental paradigm shift brought about via cloud-based computing. In cloud-based computing the software is provided using the SaaS model. In SaaS the user uses the vendor-hosted software by means of the internet. The software offered on a pay-as-you-go basis. SaaS provides users with the ability to use software almost instantly on demand. Further the SaaS model allows users to increase or decrease their usage without investing in new hardware to support a period of peak demand. Another key to the success of SaaS is that software is often accessed via the ordinary, even ubiquitous, web browser.

Web-based tools do not require download or installation beyond the typical web browser. Nor is configuration a concern. Further, user familiarity with the browser helps to reduce the learning curve for a new diagramming tool. Not only are users familiar with the browser itself, the software is designed using established standards. The commonality in design eases the user experience with new diagramming tool.

In addition, web-based diagramming tools typically offer web-based tutorials to assist students in using the tool. Such web-based tutorials help instructors transition to the diagramming tool while devoting fewer resources to developing new user guides or tutorials.

A survey of web-based diagramming tools show support for a wide range of symbol sets as shown in Table 2.

Table 2. Symbol sets supported by a variety of web-based diagramming tools.

Business Process	Organization Charts
Cause – Effect	SIPOC
Data Flow	Software Design
Database	SWOT
Engineering	UML Diagrams
Flowcharts	User Interface
Industrial Process Control	Value Stream
Mindmap	Venn
Mockups	Wireframes

Software delivered as SaaS in the cloud computing paradigm can reduce initial startup costs and sometimes a version is offered at no charge as shown in Table 3. When a fee is required to use the software, that fee may be much smaller than the outright purchase of software, reducing the entry barrier as well as start-up costs and delays.

2.2 Drawbacks of Web-based Diagramming Tools

Web-based diagramming tools are not without potential drawbacks. Accounts may be required and some students may be reluctant to register with a vendor. Free versions of the tools may limit the number of diagrams or amount of storage that can be used. There may still be a learning curve for students although web-based tools usually have web-based tutorials in the form of short videos. Otherwise the instructor may need to develop training materials for a specific product.

With web-based software one is highly dependent on the vendor. The vendor may update the product version in the middle of a course, causing confusion for students and requiring the instructor to rapidly revise materials. With purchased software the installed version continues to operate until the user installs the update. The vendor determines how accounts are managed and when maintenance will take place. When software is entirely hosted by the vendor users have little recourse if the vendor discontinues operation.

If SaaS adoption entails a fee there may be a lower start-up cost but, as Table 3 shows, recurring fees accumulate if access is needed for longer than a course.

Table 3. Examples of pricing for SaaS diagramming tools in USD.

Type of Service	**Creately**	**Draw.IO**	**Gliffy**	**Lucid Chart**	**Office Online PowerPoint**
Personal limited use	Free	Free	Free	Trial	Free
Single User-Month	--	Free	4.95	4.95	Free
Single User-Year	--	Free	47.88	39.96	Free
Single Pro -Month	5	--	9.95	9.95	--
Single Pro-Year	49	--	95.88	99.96	--
Team Pro-Month	25	--	--	25	--
Team Pro-Year	249	--	--	252	--
Education-Month	--	--	--	Free	Free
Education-Year	--	--	--	Free	Free

3 Case: Computer Science – Information Systems Analysis and Design

The information systems course sequence in a computing degree provides an example of types of diagramming needed in the computing curriculum at Webster University. In the computing curriculum the path started by COSC 2810 Systems Analysis and Design culminates in a pair of capstone courses: COSC4810 Information Systems I and COSC4820 Information Systems II. As a part of capstone courses students must demonstrate both breadth and depth of learning through an extended project. The project is covers several phases of the systems development lifecycle from feasibility through both logical and physical design. Often a prototype is developed based on the finalized design.

Students must demonstrate the application and mastery of many specialized diagrams in the process of completing the course project. The typical information systems project requires the following diagramming: Entity Relationship Diagram (ERD); System Use Case using Unified Modeling Language (UML); Dataflow Diagram (DFD); Gantt Chart; Flowchart detail where needed; Ishikawa Cause and Effect Diagram; Organization Chart; and Program Evaluation and Review Technique/Critical Path Method (PERT/CPM).

The variety diagrams needed for a single project illustrates the challenge students face in the course. The range of diagrams encompasses both STEM diagrams specific to information systems as well as business diagrams. Fewer diagramming tools provide support across disciplines, yet diagrams for a single project in information systems do cross disciplines. Using a diagramming tool helps students create

diagrams that are professional in appearance without having to worry about artistic drawing skill.

In the e-learning environment the challenge of installing and learning several kinds of diagramming tools would be too much for students particularly in the accelerated eight-week format. With the advent of web-based diagramming tools, the installation and configuration effort is removed from consideration. Further, web-based software tools are often accompanied by web-based tutorials to assist students and reduce the learning curve. An excerpt from a sample DFD is shown in Figure 1.

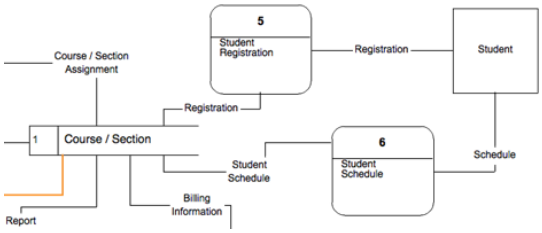

Figure 1. Excerpt from a Sample Data Flow Diagram (DFD) modeled in Creately.

During the conversion of a face-to-face course to online delivery, one instructor addressed the dilemma of diagramming tools by adopting Creately for several important diagramming techniques in the course – DFD, ERD, and UML.

The instructor created recorded tutorials addressing diagraming concepts as well as techniques using screen capture software. E-learning students were successfully able to complete the required diagrams for their course without having to install or configure software on their local machine. Furthermore, using Creately for specialized diagramming was so successful online that it was integrated into the face –to-face course as well, thereby standardizing the tools and the learning experience in the two environments.

4 Conclusion and Future Directions

Both practitioners and academics alike note the importance of diagramming to learning and practice. Drawing can help students develop skills in many areas from reasoning to problem-solving. Building on active learning, drawing can engage students while facilitating the development of internal conceptual models. Yet, relatively little research addresses the problem and potential of using specialized diagramming tools for learning in e-learning courses. The findings suggest that the specialized diagramming tools provide a fertile area for research.

Future directions may investigate the student adoption and use of diagramming along with its efficacy for learning. Comparative studies may explore the learning efficacy of hand-drawn versus software-prepared diagrams. The comparative user experience (UX) for traditional versus web-based specialized diagramming tools may be explored.

5 References

[1] Ainsworth, S., Prain, V., Tytler, R.: Drawing to Learn in Science. Science, vol. 333, (26 August, 2011)

[2] Lane, A.: A review of diagramming in systems practice and how technologies have supported the teaching and learning of diagramming for systems thinking in practice. Systems Practice and Action Research, vol. 26(4) pp.319-329, (2013)

[3] Feldstein, M., Masson, P.: Unbolting the chairs, making learning management systems more flexible. E-Learn Magazine, ACM, (2006), http://elearnmag.acm.org

[4] Rößling, G., Crescenzi, P., Ihantola, P., McNally, M., Radenski, A., Sánchez-Torrubia, M.: Adapting Moodle to better Support CS Education. In: ITiCSE-WGR'10, Bilkent, Ankara, Turkey, pp 15-27. (2010)

[5] Quillin, K., Thomas, S.: Drawing-to-Learn: A Framework for Using Drawings to Promote Model-based Reasoning in Biology. CBE Life Sci.Education, vol. 14 issue 1 pp 1-16 (2015)

[6] Manalo, E., Uesaka, Y., Perez-Kriz, S., Kato, M., Fukaya, T.: Science and engineering students' use of diagrams during note taking versus explanation. Educational Studies vol. 39 issue 1, pp. 118—123 (2013)

[7] Socha, D., Tenenberg, J.: Sketching Software In the Wild. In: 35th Annual IEEE International Conference on Software Engineering (ICSE 2013), pp. 1237—1240. IEEE, San Francisco, CA, US (2013)

[8] Yatani, K., Chung, E., Jensen, C., Truong, K. N.: Understanding How and Why Open Source Contributors use Diagrams in the Development of Ubuntu. In: 27th Computer Human Interaction (CHI2009), pp. 995—1004, ACM, Boston, MA, US (2009)