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Effective Use of Visualization in Education

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Abstract:

With the ever increasing use of computers, visualization is used more and more. Powerpoint-fatigue is a well-known fact. There's a general feeling that supportive technologies can be useful and effective in education, however those outcomes are often not achieved. Consequently people start to look for alternatives: movies, animations and infographics, have become common-practice. These are all powerful and valuable tools, also in education. It is very important though to ask what type of tool to use, for which kind of learning and to which purpose. In this article we attempt to derive a taxonomy which will help to make sound choices, so that visualization can be used effectively.

Keywords: Visualization, Learning,

I. INTRODUCTION

This paper reports on the findings from our research project, as we described last year in "Enhancing student-centric learning by building on visualization" (Abcouwer & Smit, 2011). This project was granted by ICTO, the University taskforce for ICT in education. The aim of the research project was to investigate changes in learning, dynamics and roles in education. More specifically we wanted to use the methods students are using to use supportive visualization technologies in classroom settings, and see if we could establish a model to help understand the choices, which could facilitate choosing supportive visualization technologies. The result of the research project[1] was to develop a method to facilitate choosing a supportive visualization technology, as well as a 'toolbox' of documented examples of procedures and tools, which can then be re-used. The cases were gathered during a project under the name "crowd-visualization" where students were actively involved in creating visualizations for use in the classroom.

[1] Our research project will aim to investigate the ways in which the differences in visualizations can be utilized in education, supporting the learning process. It is based on the research of Ivanova who found that by: "Digital Tools: today's students have mastered a large variety of digital tools that are like extensions of their brains" (Ivanova, 2009) {from submission 2011}

'A picture is worth a thousand words'. The question is however, how do we ensure those 1000 words are in a picture? Many times you can see pictures/illustration which add little, or worse, only increased confusion. So while we all judge instantly whether visualization is helpful, this is not so obvious to the person trying to utilize this. Determining whether and how visualization can be helpful is even more difficult. So far this has been the area of communication specialists, who are specialized in this. With the recent technological advances these capabilities are more and more within reach of everybody. This brings a need to be able to understand for what type of knowledge transfer a particular visualization technique is useful. We will focus on helping to make a choice in the face of seemingly unlimited possibilities. The consequence of these 'unlimited possibilities' is that it is de-facto impossible to discover the best supportive technology. So how can a sound choice be made?

Utilizing the visual part of our brain in addition to the rational/reading part is "is to amplify cognitive performance, not just to create interesting pictures. Information visualizations should do for the mind what automobiles do for the feet". As "Information visualization promises to help us speed our understanding and action in a world of increasing information volumes". (Card, 2008) Clearly using visualizations can be very powerful addition. People have been applying this to learning for centuries, and still are.

However there are more reasons embrace the use of new visualization technologies. "Half of what is known today was not known 10 years ago" (Siemens, 2005). "These "tools are enablers of collaboration, and therefore enablers of 21st century teaching" (Churches, 2012). In order to prepare students, teaching should be based on a similar collaborative focus. Also thinking skills are and remain vitally important, "While much of the knowledge we teach may be obsolete within a few years, thinking skills once acquired will remain with our students for their entire lives" (Churches, 2012).

In the end it is about creating meaningful learning (Mayer, 2002). "Meaningful learning occurs when students build the knowledge and cognitive processes needed for successful problem solving."

The aim is bring more understanding to the use of visualizations in education, for the purpose of learning and knowledge transfer. We will work towards a model which aims to simplify the process of choosing visualization technologies for the aim of education in a classroom setting, linking the choice to the learning objectives. Through this we hope to make it easier for educators and students to choose wisely among the various possibilities. To do this we will first review the state of literature on learning and on visualization. Next we will attempt to construct a model which can aid in the process of choosing. After which we will use cases created by students in a classroom setting to score them according to the model, and assess whether utilizing the taxonomy could have helped their choices. The assessment is done with the help of experts, teachers.

We will not be researching whether using visualizations or animations in education is worthwhile or not. This is the topic of various research, however like Thomas Naps, et all, we perceive that visualizations are 'potentially beneficial to learning outcomes and motivation (Naps, 2003)

"WHAT IS LEARNING"?

In recent papers we've attempted to choose a supportive technology based on a model using the following learning theories and Gardner's multiple intelligence.

Behaviorism as learning approach

In behaviorism, learning takes place in a repeated process of action and feedback. According to behaviorists, learning takes place in pairs, like for instance fire -> warm. Learning settles by repeating these pairs. Complex learning can occur by gradually adjusting the pairs, thus creating complex behavior. The best results are achieved by positive affirmation of behavior. Skinner's (1958, 1972) view on learning has been highly influential in the field of education. In his view, learning is the observable change in behavior. This approach has resulted in teaching machines that were created by Pressey (1926, p.374) but made popular by Skinner (1958). These machines evolved into computer-aided instruction and computer-based training and next to web-based training and learning.

In education, the main characteristics of behaviorism are the focus on positive and negative affirmation of behavior, as well as a constant need for tests and feedback.

Cognitive learning

The cognitive approach to learning has been established as a response to behaviorism. Apart from the observable behavior that behaviorists believe in, internal processes are also important (Valcke, M.M.A., 2000). Therefore, this approach is focused on: knowing, obtaining knowledge, internal mental structures. The brain is not seen as a black box. There is explicit attention to invisible things like memory, reasoning, thinking and reflection. The main focus is on guiding the student in using the right learning strategy and helping to relate new knowledge to existing knowledge. Consequently, knowledge can be represented schematically, linking one item of knowledge to another.

Guidelines for cognitive learning are: an active involvement of the student, hierarchical analyses, knowledge building on the basis of other knowledge, structuring, organizing and sharing knowledge, creating a learning environment that enables and encourages students to make connections to existing knowledge and finally, using progress tests and final tests to monitor progress.

Social Constructivism

Constructivism states that people put a meaning on experiences in their own way (Bartlett et al, 2001). According to Bartlett (2001), one of the major founders of constructivism is Jean Piaget, who starts from the idea that a person absorbs certain experiences into his already existing knowledge. He calls this process assimilation (Cole et al, 2001). In addition, a person can rearrange his own concepts in such a manner that the new concept can be included. This is called accommodation. This knowledge construction process, consisting of assimilation and accommodation, can only take place when the experiences in some way connect to the existing concepts. If this is not the case, then the person will not absorb the knowledge and therefore not learn anything.

Lev Vygotsky and Jerome Bruner added the social component to constructivism. They assumed that communication represents a strong added value in the learning process. Vygotsky even states that the use of language itself influences a concept, whilst for Piaget language was only a means for communicating concepts (Bartlett et al, 2001).

Learning within social constructivism consists of creating and arranging concepts in the brain. Therefore, this is not learning fragmented knowledge by heart but the development of meaningful concepts on the basis of experiences and a realistic context (Kral, 2005; Kolb, 1984). The teacher has the task to create a meaningful situation in which the individual student constructs his or her own knowledge (Bartlett et al, 2001). A student should be given the responsibility to design his or her own learning experience. Monitoring one’s own learning process plays an important part. Monitoring and checking one’s own learning process is known as metacognition. Cognitive processes are split into two levels: the object level and the meta level. The meta level plays a monitoring and checking part with regard to the object level (Cox, 2005). Reflection and feedback are part of the meta level and for that reason are of crucial importance to the learning process (Kral, 2005).

All this makes learning into a social activity, which is carried out together with others. By means of collaborating and communicating, the student is obliged to clarify his thoughts and he is confronted with the weaknesses of his ideas. This principle also applies when a student explains a subject to himself (Van Lehn et al, 1993).

A more recent implementation of the ideas of social constructivism can be found in the Natural Learning approach as founded by Van Emst (2002).

Connectivism

As a reaction to the limitations of the other three models, connectivism is proposed to explain the impact of new technology on learning. Learning has always been considered a process inside an individual, yet according to connectivism, learning is a process that may occur outside the individual, within an organization or database.

The basis of connectivism is formed by principles that are explored by chaos, network and complexity and self-organization theory. Seemingly hidden patterns should be recognized, instead of understanding by sensemaking tasks as for instance in constructivism. Furthermore, a student should be able to adopt to a pattern shift. So the e-environment will also need to be informationally open and its structure changeable.

The connections by which we can learn are more important than what we currently know, i.e. “the pipe is more important than the content of the pipe” (Siemens, G., 2004). Finding and maintaining connections enables a student to learn more successfully. The combination of ideas created by weak links can create new innovations and insights.

Connectivism starts from the individual, whose knowledge is comprised of a network. The individual feeds this into organizations and institutions, which in turn feed back into the network, giving the individual the possibility to continue learning. This cycle of learning is instrumental in successful learning.

Where Abcouwer & Smit (2009) found that approaching the question of choosing supportive technologies solely on the basis of learning theories didn’t encompass the whole story. When looking at the link between learning theories and supportive technologies a very important element was missing. The learning theories describe how information is absorbed, processed and retained. However it doesn’t look at the process of learning. Ireland (2007) created an overview of the learning theories. From his overview we can learn that the process is vitally important, as the methods used for knowledge transfer are quite different, as well as the way learning occurs. The types of learning which can be explained by the learning theory also differ. Hence, visualization techniques must adapt to the appropriate learning theory. So while “a learning theory comprises of the underlying psychological dynamics of events that influence learning” (Ormrod, et al, 2008), the process is important as well. The learning theories focus on explaining how people learn, but do not take the process of learning into consideration. To take the process of learning into account educators traditionally have turned to Bloom’s taxonomy. Helping them plan curricula to achieve learning objectives.

THE BLOOM TAXONOMY

Bloom's model (1956) was originally built in the 1950's upon 3 domains of educational activities: Cognitive, Affective & Psychomotor, commonly referred to as KAS (Knowledge, Attitude & Skills). The Bloom Taxonomy is based upon the cognitive domain, which will be where we will focus as well. The use of visualization most likely also has an effect on the attitude and skills domains, but for now those are not part of the scope here.

The Bloom model has been built up on 6 levels of cognitive complexity, going from concrete to abstract. The original taxonomy was explicitly "represented as a cumulative hierarchy" (Krathwohl, 2002). It was intended to give "an organizational structure that gives a commonly understood meaning to objectives classified in one of its categories, thereby enhancing communication".

In the early 1990's the Bloom Taxonomy, then already over 40 years old, has been revised to fit the 21st century situation. While the taxonomy had been mainly aimed at teachers to help design a curriculum and assessments, more and more examples came up of people applying it in different settings and circumstances. Also Bloom himself believed the taxonomy could serve a wider purpose. Consequently a group led by Krathwohl set out to update the taxonomy, adapting it for use in the 21st century. This time "representatives of three groups [were present]: cognitive psychologists, curriculum theorists and instructional researchers, and testing and assessment specialists" (Anderson, & Krathwohl, 2001, p. xxviii) (Krathwohl, 2002 - a revision of Bloom's Taxonomy: An Overview)

A number of changes were made: terminology, structure and emphasis. The list below shows the changes in terminology. Secondly the order of evaluating and creating was changed.

Remembering	Recalling previously learned information, a slight change from recalling data or information, with an emphasis on what's learned before.
Understanding	Very similarly defined, yet the category was relabeled to Understanding (vs Comprehension).
Applying	no change
Analyzing	no change
Evaluating	position in the model was changed
Creating	Bigger emphasis on this part.

Table 1: Overview of changed terms[2]

To see how these levels would work take a look at the examples below:

[2] Source: Clark, D., http://www.nwlink.com/~donclark/hrd/bloom.html

Remembering	What are the health benefits of eating apples?
Understanding	Compare the health benefits of eating apples vs. oranges.
Applying	Which kinds of apples are best for baking a pie, and why?
Analyzing	List four ways of serving foods made with apples and explain which ones have the highest health benefits. Provide references to support your statements.
Evaluating	Do you feel that serving apple pie for an after school snack for children is healthy? Why or why not?
Creating	Convert an "unhealthy" recipe for apple pie to a "healthy" recipe by replacing your choice of ingredients. Explain the health benefits of using the ingredients you chose vs. the original ones.

Table 2: Examples of cognitive processes

Finally, knowledge dimensions were added, as to allow them to be explicitly addressed. So in effect the taxonomy now consists of a knowledge dimension – "*what type of knowledge to learn/transfer*", and a cognitive dimension – "*what process to use*"[3]. Resulting in a 6 by 4 matrix.

Summary of the Revised Taxonomy

The revised 21st century version of the Bloom Taxonomy is in the table below. To get an insight in the taxonomy we will firstly discuss the knowledge dimensions and then the Cognitive process dimension.

3 http://projects.coe.uga.edu/epltt/index.php?title=Bloom%27s_Taxonomy#Revised_Bloom.27s_Taxonomy_.28RBT.29

	Cognitive Processes					
The Knowledge Dimensions	1. Remember	2. Understand	3. Apply	4. Analyze	5.Evaluate	6.Create
Factual	1	2	3	4	5	6
Conceptual	7	8	9	10	11	12
Procedural	13	14	15	16	17	18
Metacognitive	19	20	21	22	23	24

Figure 1 The revised Taxonomy of Bloom

Knowledge dimensions

There are 4 knowledge dimensions: Factual, Conceptual, Procedural & Metacognitive. Each of these is divided into several sub-dimensions which will be illustrated below:

Factual Knowledge: basic elements students must know to be acquainted with a discipline or solve problems in it

- Knowledge of terminology: Technical vocabulary, symbols
- Knowledge of specific details and elements: knowing reliable sources of information

Conceptual Knowledge: The interrelationships among the basic elements within a larger setting that enable them to function together.

- Knowledge of classifications and categories: generations
- Knowledge of principles and generalizations: for example, Pythagorean theorem, law of supply and demand
- Knowledge of theories, models and structures: theory of evolution, structure of organizations

Procedural Knowledge: How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods

- Knowledge of subject-specific skills and algorithms: whole-number division, searching the internet

- Knowledge of subject-specific techniques and methods: interviewing techniques, scientific method
- Knowledge of criteria for determining when to use appropriate procedures: when to apply Newton's second law, when to use a particular method of estimation

Meta-Cognitive Knowledge: Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.

- Strategic knowledge: outlining as a means of capturing the structure of a unit of subject matter in a textbook
- Cognitive tasks: knowledge of the different types of tests, cognitive demands of different tasks
- Self-knowledge: knowledge that critiquing essays is a personal strength, whereas writing essays is a personal weakness; awareness of one's own knowledge level

Meta-Cognitive knowledge is a new category, introduced in the revised taxonomy. There are three types of meta-cognitive learning which are of particular importance: Strategic knowledge, knowledge of tasks and self-knowledge (Pintrich, 2002). Strategic knowledge refers to knowledge of strategies of learning and thinking. Knowledge of tasks represents knowledge about different types of cognitive tasks, as well as classroom and cultural norms. Self-knowledge finally, is a critical component of meta-cognitive learning, as it reflects the way students learn (Pintrich, 2002).

Cognitive Processes

Now we will discuss the sub-processes within each of the cognitive processes. This is needed to help evaluate visualization technologies later on. To keep things clear the descriptions will be as short as possible, where possible they'll be illustrated as examples:

Remembering: retrieve relevant knowledge from memory

- Recognizing: Recognize dates and facts
- Recalling: recall important dates and facts

Understanding: Construct meaning from instructional messages, including graphic communication

- Interpreting: Paraphrase important documents.
- Exemplifying: Give examples of various artistic painting styles
- Classifying: Classify observations
- Summarizing: observed events

- Inferring: for example, when learning a foreign language infer grammatical principles from examples
- Comparing: compare historical events to current situations
- Explaining: Explain the cause and important of various events.

Applying: use a procedure in a situation

- Executing: carry out a division of numbers
- Implementing: determine in which situation a certain principle is applicable.

Analyzing: break material into its constituent parts and determine how the parts relate to one another.

- Differentiating: distinguish between relevant and irrelevant facts
- Organizing: Structure evidence to support or counter and argument
- Attributing: Determining the point of view of an author in terms of his/her political view

Evaluating: make judgments based on criteria

- Checking: determine whether conclusions are supported from the 'data'
- Critiquing: judge which of two methods is best to solve a problem

Creating: put elements together, or reorganize to form a new pattern or structure

- Generating: generate hypotheses to account for an observed phenomenon
- Planning: plan a research paper
- Producing: Built systems for certain purposes.

So we end up with the following model:

	The Cognitive Process Dimension					
The Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	List	Summarize	Classify	Order	Rank	Combine
Conceptual Knowledge	Describe	Interpret	Experiment	Explain	Assess	Plan
Procedural Knowledge	Tabulate	Predict	Calculate	Differentiate	Conclude	Compose
Meta-Cognitive Knowledge	Appropriate Use	Execute	Construct	Achieve	Action	Actualize

Table 3: overview of the revised Bloom taxonomy[4]

Below on the basis of the definitions of the cognitive processes follows a table to assist in categorizing:

Cognitive Process	keywords	examples
1. Remember	Describe, Name, Relate, List, Write, Find, Tell, Recognize, Identify, Retrieve, Locate, Find	Bookmarking, social networking, social bookmarking, googling, searching
2. Understand	Explain, Compare, Discuss, Restate, Predict, Translate, Outline, Interpret, Summarize, Infer, Paraphrase, Explain, Exemplify	Advanced searches, Boolean Searches, blog journaling, twittering, categorizing, tagging, commenting, annotating, communicating, social networking

[4] Source: http://oregonstate.edu/instruct/coursedev/models/id/taxonomy/#table (Retrieved on 1st of august 2012)

3. Apply	Show, Complete, Use, Classify, Examine, Illustrate, Solve, Implement, Carry Out, Execute	Running, Loading, Playing, Operating, Uploading, sharing, editing, recording,
4. Analyze	Compare, Explain, Examine, Categorize, Identify, Contrast, Investigate, Organize, Outline, Structure, Integrate	Linking, validating, media clipping, polling, timelines, concept organizing,
5. Evaluate	Assess, Justify, Prioritize, Recommend, Decide, Rate, Choose, Check, Hypothesize, Critique, Experiment, Judge, Test, Detect, Monitor	Blog commenting, reviewing, posting, moderating, collaborating, networking, testing, evaluating and critiquing
6. Create	Invent, Plan, Compose, Construct, Design, Imagine, Produce, Devise,	Programming, filming, animating, blogging, video, mixing, wiki-ing, publishing, videocasting, podcasting, directing, broadcasting

Table 4: Overview of Cognitive processes

Knowledge Dimension	keywords	examples
Factual	Terminology, facts, elements, names	Alfabet, Mathematical symbols, Musical notation, Names of politicians
Conceptual	Classifications, categories	Species of animals, Newton's law of physics,
Procedural	How to do something, procedures, methods	Solving a mathematical equation, mixing colors, statistical analysis

		procedures.
Metacognitive	Knowing strategies, which and when to use. Self-reflection	How to memorize, Outlining, concept-mapping, problem solving and thinking.

Table 5 - Overview of Knowledge dimension

INTEGRATING THE LEARNING THEORIES WITH BLOOM

The Bloom taxonomy has been extensively used for designing curricula, however recently people have started to explore the possibilities of using the taxonomy to map web2.0 technologies for personal use. To be able to extend this for use in a education/classroom setting it is needed to also consider the learning theory. Therefore we propose to link the learning theories to the Bloom taxonomy as a model of choosing a supportive visualization technology. This way we can include both the learning approach as well as the learning objectives.

Mapping the learning theories

Behaviorism

This learning theory revolves around repetition, and given the students tasks. Consequently on the knowledge dimension it mainly focusses on factual, conceptual and procedural knowledge. For the cognitive process dimension, the main focus lies on remember, understand, apply. Also slightly into analyze and evaluate. Mapping this onto the Bloom taxonomy gives the following table[5]. White cells consist of learning objectives not accounted for in behaviorism.

Keywords: internalization, repetition, skills, black-box, task-based and stimulus.

	Cognitive Processes					
The Knowledge Dimensions	1. Remember	2. Understand	3. Apply	4. Analyze	5.Evaluate	6.Create
Factual	1	2	3	4	5	6

[5] White areas are not accounted for in Cognitivism.

Conceptual	7	8	9	10	11	12
Procedural	13	14	15	16	17	18
Metacognitive	19	20	21	22	23	24

Figure 2 Linking Behaviorism to Bloom

Cognitivism

Learning in cognitivism builds on earlier knowledge, still using a repetitive process, where storage, retrieval and encoding are important elements. Creating a clear, repeatable reasoning.

Keywords: structured / existing scheme, previous experiences , encoding, storage, retrieval, duplicating, reasoning, clear objectives, problem solving

	Cognitive Processes					
The Knowledge Dimensions	**1. Remember**	**2. Understand**	**3. Apply**	**4. Analyze**	**5.Evaluate**	**6.Create**
Factual	1	2	3	4	5	6
Conceptual	7	8	9	10	11	12
Procedural	13	14	15	16	17	18
Metacognitive	19	20	21	22	23	24

Figure 3 Linking Cognitivism to Bloom

(Social) Constructivism

Learning is seen as an active, engaged process. A process of constructing knowledge. The meta-cognitive level is center-stage, as thinking-skills are the top-objective. ‘Social negotiation’ is part of the process (Muir, 2001).

Keywords: social, personal, subjective, remixed, group feedback, and self-evaluation.

	Cognitive Processes					
The Knowledge Dimensions	1. Remember	2. Understand	3. Apply	4. Analyze	5.Evaluate	6.Create
Factual	1	2	3	4	5	6
Conceptual	7	8	9	10	11	12
Procedural	13	14	15	16	17	18
Metacognitive	19	20	21	22	23	24

Figure 4 Linking (social) constructivism to Bloom

Connectivism

Cornerstone of connectivism is the network, and learning through the network and it's connections. Student is working collaboratively. The network is more important than the lessons' learned, in other words a heavy focus on the meta-cognitive dimension.

Keywords: network, process, distributed, adaptive patterns, complex learning, diverse sources, diversity of opinions, subjective and decision-making.

	Cognitive Processes					
The Knowledge Dimensions	1. Remember	2. Understand	3. Apply	4. Analyze	5.Evaluate	6.Create
Factual	1	2	3	4	5	6
Conceptual	7	8	9	10	11	12
Procedural	13	14	15	16	17	18
Metacognitive	19	20	21	22	23	24

Figure 5 Linking Connectivism to Bloom

USING THE MODEL

From the previous overview it is clear that the Bloom taxonomy features a whole set of learning objectives, which are not always applicable in a given learning theory. To choose a supportive visualization technology it is therefore firstly important to determine the learning approach chosen. Given this learning approach, the learning objectives can be selected. Next we will categorize various supportive visualization technologies in the model. Each supportive visualization technology will be categorized under one or more learning theories, and the learning objectives in the taxonomy. This way we have a rich set which enables us to choose.

CATEGORIZING VISUALIZATION TECHNOLOGIES

Based on the theoretical framework we have categorized a number of technologies.

In this paragraph we will use the model to categorize a number of often used visualization technologies. The technologies have all been chosen from the list of Top 100 of 2011 tools for learning as compiled by the Center for Learning & Performance Technologies . This list is compiled through a questionnaire among professionals and enthusiasts on a yearly basis. It is comprised of many different kinds of supportive technologies, amongst them visualization technologies. For the purpose of this study we will merely categorize technologies that have been employed by students in the cases.

In the next part we will see in what situations students have used the visualization technology, and see if that matches with what the model suggests. But first we will categorize the visualization technologies according to the taxonomy.

We will look at the following technologies/techniques.

- Powerpoint
- Prezi
- Info-graphics
- Wordle
- Mind-maps
- Animations
- TED Talks

Method of categorization

For each technology we will match with the knowledge dimensions and the cognitive processes used, based on the descriptions before, see page 2 and 2. Establishing for what kind of knowledge transfer it can be used most effectively. Next we'll categorize it on cognitive process, or process used in learning, to see in which circumstances it can be used best.

Visualization technologies

Powerpoint,

Learning Theory: predominantly behaviorism, cognitivism and (social) constructivism.

Knowledge dimension: can be used for all, however isn't especially geared to a particular dimension. Not very appropriate for the metacognitive dimension, as it can merely list a strategy, but not apply.
Factual / Conceptual / Procedural / Meta-Cognitive

Cognitive process: Most appropriate for lower order learning. Can be used by students in a classroom setting to analyze, and share.
Remember / Understand / Apply

Prezi

Learning Theory: any

Knowledge dimension: seems particularly useful in conceptual and procedural knowledge, can be applied for factual as well.
Conceptual / Procedural

Cognitive process: while it can be seen as a presentation package with a twist, its strength lies in the dimensions of understanding, analyzing and perhaps create. Can be used to explore or devise complex structures.
Understanding / Analyzing / Create

Info-graphics

Learning Theory: Behaviorism, cognitivism

Knowledge dimension: Useful for all but meta-cognitive knowledge transfer. Road-signs and flight-emergency cards are well known examples.
Factual / Conceptual / Procedural

Cognitive process: Most appropriate for lower order learning, insight into highly complex, yet factual data, and structures.
Understanding / Analyzing / Create

Wordle

Learning Theory: Behaviorism, cognitivism

Knowledge dimension: factual only. Just gives an overview of terms/words, semi- to unstructured.

Factual

Cognitive process: Remember.

Remember

Mind-maps

Learning Theory: mainly (social) constructivism & connectivism

Knowledge dimension: While these can be used for factual information, its strength lies in the other 3 dimensions.

Conceptual, Procedural, Meta-Cognitive.

Cognitive process: Most applicable in classifying, categorizing and planning.

Understand / Apply / Analyze / Create

Animations

Learning Theory: any

Knowledge dimension: While possible to apply in practically all knowledge dimensions, due to the labour-intensity of using animations its most applicable in Procedural and metacognitive.

Procedural, Meta-Cognitive

Cognitive process: With the exception of Create, all other cognitive processes can be supported by animation.

Remember / Understand / Apply / Analyze / Evaluate

TED talks

Learning Theory: any, but most likely (social) constructivism and connectivism.

Knowledge dimension: In this case the dimension is determined not so much by the possibilities of the technology, but by the available content. Consequently this fits best with the Meta-Cognitive process

Meta-Cognitive

Cognitive process: generally aimed at higher order learning.

Analyze / Evaluate / Create

CASES

The cases were taken from the courses Knowledge management & organization (3rd year Bachelor IS curriculum), and Business Information Systems (2nd year IS curriculum) where, as part of the course-requirements, the students were given the assignment of creating a visualization of a topic. During an introduction class the background and possible uses of supportive visualizations were discussed, as well as a number of examples, good and bad. After which students could decide on what exact topic they would pick, naturally within the context of the class. In the business information systems class students would work together as a project team on creating a visualization, as a collaborative assignment. In the knowledge management & Organization class students were given individual assignments. The classes were both structured according to the social constructivist learning approach, as there was an emphasis on the group-process. The end result of the assignments were evaluated by the learning professional (teacher).

The students deliberately did not used the model yet, as we wished to evaluate whether the resulting choices would be different. During the introduction class there has been an emphasis on which type of visualization technology to choose. All students were either part of the masters of Information Science, or an Economics program.

As a consequence of this particular group of students the technological learning curve isn't very important in this. However when applying this model elsewhere it should be noted that the learning curve in using various visualization techniques can be steep. This is something which has not been taken into account of this research.

This has merely been an preliminary attempt to evaluate the use of the model, and is not meant to replace a more formal test, which is a matter for further research.

CASE EVALUATION

Per case we will first describe the purpose for which the visualization is intended. Based on this we'll use the model to find which areas are important, and which visualization technique it would recommend.

Next we'll describe the method chosen and used by the students. The educational professional will give his/her judgment on whether the visualization was fitting and purposeful or not. Finally we'll see if the choice made by the students fits with the recommendation by the model.

Case 1 – Legacy Systems

Learning theory: social constructivist
Objective:

What are the problems of legacy systems, how did they come about, and how can you deal with them.

Created as an animation of just under 3 minutes, in which the origins of this issue are discussed and illustrated. Also the legacy systems issue is analyzed and evaluated. The problems are discussed, including the causes. The aim is that students understand and are capable of explaining and assessing this issue, and using this knowledge.

Categorize:

Describing consequences of legacy systems and strategies of how to deal with them.

Analyzing (identifying and comparing) and evaluating (Assess, critique) the results.

Meta-Cognitive,

Analyze & Evaluate.

Applied visualization technology:

Animation.

Recommended visualization technology:

From the categorization follows that using an animation is a feasible option. Another option suggested is looking for a TED-talk on this particular subject.

Case 2 – Overview of Knowledge management

Learning theory: social constructivist

Objective:

Give an overview of the subject of Knowledge management based on the book by Etienne Wenger. Outline the various elements, in the order that they will be dealt with and illustrate the congruence of the topics.

Categorize:

Conceptual

Understand

Applied visualization technology:

Interactive InfoGraphic. An interactive map in which the various elements are clickable to dive deeper into the presented information.

Recommended visualization technology:

In accordance with the taxonomy InfoGraphics can be used for these objectives.

Alternative options from suggested by the taxonomy are: powerpoint / prezi / mindmap.

Case 3 – Communities of practice, an overview

Learning theory: social constructivist

Objective:

Overview of Communities of Practice. Objective is to show the complexity of the theory, as well as an overview of terms presented. Especially a link to the chaos theory.

Categorize:

Conceptual

Analyze

Applied visualization technology:

Powerpoint was the chosen visualization technology.

Recommended visualization technology:

Prezi / InfoGraphic /mind-maps.

The chosen visualization technology does not match with the choices suggested on the basis of the model. In fact Powerpoint is not well suited for this particular learning objective. The result was indeed deemed to be less than desirable, not adding to the clarity.

CONCLUSION

From the theory we have seen that using supportive tools can be an important element to use in education. Next we constructed a model based on learning approaches and learning objectives to map supportive visualization technologies. By combining these two approaches we created a model to help choosing a supportive visualization technology, while taking into account both the process of learning and the method of learning (learning theories). This way the suggested supportive visualizations depend both on the learning approach as well as the learning objectives. Using this model we did a preliminary test through cases created by students.

We categorized a number of visualization technologies, to test the model. Also we evaluated visualizations created by students for use in a classroom setting, and tested whether the technology they choose to employ is suggested by the model or not.

Very preliminary we've seen an example where a visualization technology was applied, which was according to the model not suitable for the learning objective at hand, and it was not evaluated positively.

This indicates a potential usefulness of this model, which needs to be verified by testing it. Which is my first recommendation for further research. In order to test this model it has to be tested for each of the learning theories, for the various learning objectives. But before this can be done, a more complete categorization of supportive visualizations technologies need to be done.

FOR FURTHER RESEARCH

Clearly doing a formal test of this model is the next step to be taken. However looking again at Gardner's multiple intelligence could also be interesting. These are often referred to by teachers, who observe that different students have different strengths, and they learn in different ways. Investigating whether the theory on multiple intelligences can add to the method of choosing supportive visualization technologies would be interesting.

Also an investigation into the influence of the various learning styles by students could be worthwhile. This might slightly overlap with the multiple intelligences.

LIST OF STUDENT CREATED VISUALIZATIONS

Assignment: Visualize a part of the Knowledge management Book by Etienne Wenger:

Nr.	Type Visualization	Knowledge Dimension	Cognitive Process
1	Prezi	Meta-Cognitive	Remember/Understand
2	Video	Conceptual	Analyze
3	Tekening	Meta-Cognitive (reflection)	Evaluate
4	Infographic	Conceptual/Meta-Cognitive (Outline)	Analyze
5	Kennisclip	Reflection	Evaluate
6	Tumbler/Blog	Factual	Understand
7	PPT	? (unclear)	? (unclear)
8	MindMap	Conceptual	Understand
9	Mindmap	Conceptual	Understand
10	Infographic	Conceptual	Analyze
11	Conceptmap?	meta-cognitive	Apply/Analyze
12	Prezi	Conceptual	analyze / structure / Explain (Understand
13	Prezi	Factual	Remember
14	Video/animation	Factual	Understand
15	Prezi	Factual	Remember
16	PDF/MindMap	Conceptual	Understand
17	PDF/MindMap	Conceptual	Understand
18	PPT	Factual	Understand
19	Mindmap (ipad)	Factual	Remember
20	MindMap (Ipad)	Factual	Remember

Opdracht: Student projects

1	Research COP with Logica NL	mindmap
2	AerData - COP	Prezi
3	Human resource management at KLM	movie
4	Knowledge management at NautaDutilh	Infographic

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