VISUALLY ENHANCED DATA ANALYTICS: LEARNING MODULE DESIGN BASED ON MEANINGFUL LEARNING

Hairulliza Mohamad Judi[1] , Zanaton H Iksan[2,] and Noraidah Sahari @Ashaari[1]

[1]*Fakulti Teknologi & Sains Maklumat, Universiti Kebangsaan Malaysia*
[2]*Fakulti Pendidikan, Universiti Kebangsaan Malaysia*

ABSTRAK

Among the main issues in data analytics learning relate to in-depth understanding and concept integration. Meaningful reception learning theory demonstrates cognitive visual tools to organize knowledge by linking new information with existing concepts in strong cognitive structure. This study identifies important attributes in data analytics and proposes a cognitive visual model to enhance learning efficiency. The study applies meaningful reception learning theory by providing users with three types of instructional design as visual cognitive support to build strong understanding structure i.e. active, collaborative and constructive. The model is expected to help instructors in systematically organizing data analytics materials for efficient learning.

1 INTRODUCTION

Data analytics is a process of examining, presenting and explaining data in a way that is easy to understand and useful to users. Data analytics plays an important role in conveying description and meaning to numbers and figures to be used by decision makers in the relevant field, or otherwise data are wasted and useless. Teaching and learning of data analytics in higher education institutions receive numerous attentions and efforts to improve the quality of teaching and student learning especially to enhance students' engagement and to promote their understanding of particular concepts. Various negative perceptions relating to the courses as difficult, and unpleasant (Krause et al. 2009; Neumann et al. 2013).

Many students report their difficulties to comprehend and utilize statistical concepts and procedures (Broers & Imbos 2005). Students rarely have the opportunity to develop in-depth understanding of what they have learned and soon they forget about the concepts after completing the course (Mulder et al. 2014). These difficulties cause students to tend to memorize the procedures without really understanding the process. Failure to develop an in-depth understanding of concept integration affects the clarity of learning and retention of student knowledge. This is also one of the reasons why students remain in the novice level in statistical thinking even though they have been exposed to various statistical bases (Lane-Getaz 2013).

Data analytic pedagogy emphasizes the ability to evaluate and think statistically in data analytic curriculum (Zieffler et al. 2018). This includes the importance of preparing students in ways and techniques to apply statistical analysis in a variety of different contexts, familiarizing them to think and making statistical reasons in various situations, as well as raising awareness and acceptance of these technological developments. A meaningful learning approach is thought to be accurate and appropriate for its effectiveness in helping students build a more in-depth understanding of statistics and preparation for application in the real world.

The emergence of data visualization as one of the new technologies has been a dominant element in higher education in line with game-based learning and analytic learning (Ngambi 2013). Data visualization or visual data analysis can potentially enhance optimum learning interactions including how and when students and teachers interconnect and engage with their knowledge, peers and environment (Tarling & Ngambi 2016). Visual tools may produces meaningful learning (Ngambi 2013), but its achievement and effectiveness do not come automatically but require a planned learning strategy (Castillo-manzano et al. 2016; Mcgarr & Gavaldon 2018)..

The problems posed by the current scenario in data analytics learning show the need for cognitive visual support to assist instructors in developing better problem-based learning materials in their assignments and for providing a instructional assistance for students building their knowledge and problem-solving skills. Thus, this study proposes specific framework as a compilation of all required ideas, concepts, examples, scenarios, as a structured and organized material to provide the support needed by these students in data analytics learning. Therefore, this study identifies important attributes in data analytics and proposes a cognitive visual model to enhance learning efficiency.

The scope of the study is set to cover data analytics courses offered at higher education levels that demonstrate the technical characteristics, complexity and current patterns of meaningful literacy and understanding of data. This study limits data analytics to widely used techniques of statistical analysis and learning outcomes focusing on statistical skills over those skills related to data mining and machine learning.

2. VISUALLY ENHANCED CLASS FOR MEANINGFUL LEARNING

Meaningful Reception Learning Theory was developed by Ausubel who suggested that students be supported with relevant facts to better understand the lesson. For example, advance organizers are practiced as a strategy to integrate main ideas before lessons begin (David P Ausubel & Fitzgerald 1961). The organizer give a comprehensive overview of concepts to enhance students' engagement and curiosity (David P Ausubel 1962).

Similarly, the presentation of ideas using concept map enables students to relate the connection between concepts and to explain complex concepts (Ameyaw & Okyer 2018). Concept map does not only facilitate meaningful learning (ML). It builds knowledge through a strong framework by connecting the new context with the old ones, and enhancing knowledge retention for long term. Concept map is able to highlight key ideas that enhance brain stimulation to process and advocate knowledge in hierarchical order, thereby enhancing learning achievement (Chiou 2008, 2009).

Scaffolding such as concept maps stimulates new knowledge and understanding based on existing knowledge by linking existing knowledge to newly learned concepts using information integration (D.P. Ausubel 2000; Cobb 1994; Novak 2002). Learning is meaningful when students understand what they are learning and begin to use their knowledge in daily practice (de Sousa et al. 2015). Hence, students are able to gain many learning benefits through practice and activities. To create a learning environment with such an element, educators should be able to understand students with the purpose and content of learning including encouraging students to participate actively.

According to (David P Ausubel & Fitzgerald 1961), meaningful learning is the process of linking new information with existing concepts in cognitive structure. In meaningful learning, prior knowledge was considered the most important in teaching and learning process (D. P. Ausubel et al. 1980). In this way, new information is combined with existing ones to update cognitive structure, significance and attribution. Students do not memorize, but learn logically and meaningfully through planned activities that manipulate intellectual development (Guimarães et al. 2018).

This study identifies the components in meaningful learning by referring to the meaningful learning model developed by (D. H. Jonassen 1995). This model was refined among others, are by (David H. Jonassen et al. 1999). The model suggests that meaningful learning elements can be divided into five items that are active, constructive, cooperative, authentic, and purposeful. This meaningful learning feature should be embedded in the learning model as a learning process.

Active learning can be defined as cognitive activities that involve students in doing something and thinking about what they do to make it clear and be able to adapt to new knowledge (M. Tan & Hew 2016). This is because learning is based on the process of appreciation of the new concept. Students have the ability to learn and adapt to the environment through experimentation and manipulation of the environment using existing tools and information.

Constructive element is closely linked to Constructive Learning Theory, suggests that individuals build their own understanding and knowledge through their own experience (Hill 2005). Hence, students are responsible for finding their own knowledge and learning new things that can be utilized in expanding the potential (Mensah 2015).

Collaborative learning refers to the environment in which a group of students engage in learning tasks and requires each individual to contribute to the group and be responsible for each other (Ahmad & Bayat 2012). Therefore, cooperation to find understanding, meaning or an important solution is needed to create an effective learning environment. Peer networks built into collaborative groups allow students to support each other socially and academically including helping students in dealing with common difficulties such as stress and isolation (Fan et al. 2015). This network serves as a solid foundation for effective peer-to-peer learning because of strong impetus and accumulated energy to solve learning problems effectively where students are comfortable and willing to share their knowledge and experience, exchange ideas, and help each other (Li et al. 2013).

Authentic learning refers to real-world learning. Authentic educational techniques emphasize the relevance of taught concepts with actual scenarios regarding problems and applications (Herrington et al. 2003; Herrington & Parker 2013). Authentic learning can encourage students' interest because these learning materials are relevant to their lives and environment (H. Y. Tan & Neo 2015). Students also become more prepared in the future as learning materials reflect the real life context and can equip themselves with practical and useful skills (Karki et al. 2018).

Purposeful learning comes from student’s intention in fulfilling educational goals. Learning becomes most meaningful when it is intentional and has a clear goal (David H Jonassen & Strobel 2006). Students follow the learning process to meet certain goals especially to achieve cognitive and affective maturity. If students are actively learning and deliberately trying to achieve cognitive goals, they think and learn effectively as they work to fulfill their intentions and desires.

Due to its close relevancy to data analytics learning, three strategies, i.e. active, collaborative and constructive elements will be implemented in the study. Despite their practical application in data analytics learning, these approaches have not yet discussed in detailed regarding their implementation in the domain based on ML. Analysis on literature review provide comparison study regarding ML strategies to address students problem in related course. Table 1 provides the comparison. Collaborative learning appears to be among popular applied meaningful elements in the study.

TABLE 1. Meaningful learning (ML) study using cognitive tool

Study	**Learning aid strategy**	**ML element**	**Tool**
(Denham 2018)	Digital game	Constructivist	Advance organizer
(Chiou 2008)	Feedback to completed task	Active	Concept map
(Wehry et al. 2010)	Select-and-fill-in knowledge	Active	Concept map
(Doorn & Brien 2007)	Active learning	Collaborative	Concept map
(Gidena & Gebeyehu 2017)	Teacher dominant	Purposeful	Advance organizer
(Roessger et al. 2018)	Traditional teaching, traditional +relational framing, feedback	Active	Concept map
(Hickey 2018)	Feedback from peer and expert	Collaborative	Concept Map
(Taguchi & Matsushita 2018)	Deep learning	Collaborative	Concept map

The design and development of proposed model is part of research activities using ADDIE instruction model. ADDIE model is a systematic design guide using dynamic and flexible approaches to build effective teaching modules (Aldoobie 2015). Figure 1 presents main activities in design phase i.e. modeling scaffolding for data analytics learning, identifying component attributes and frames for relevant ML strategies, and designing scaffolding for the strategy.

Cognitive visual support model focuses on data analytics knowledge construction and problem solving. Figure 2 present the model which consists of two main divisions namely Preliminary and Scaffolding. Preliminary part concerns on the knowledge background of learning process. Scaffolding part emphasizes the learning support.

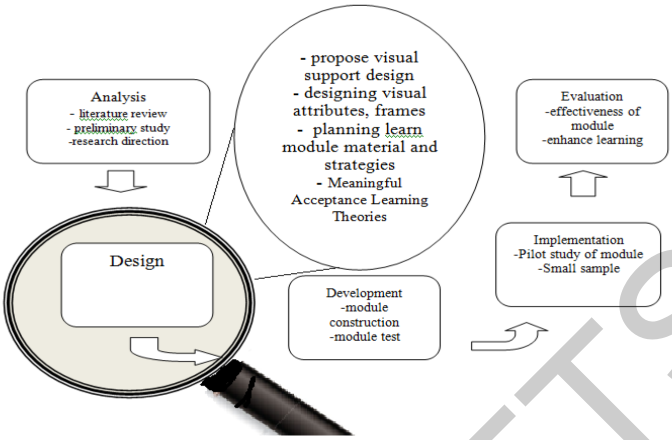
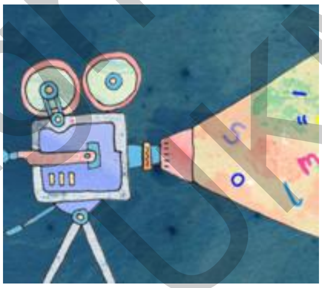


FIGURE 1. Design phase in ADDIE instruction model

Element	Key indicators	Visual enhancement	Designed activities
Active 	Interact with learning content Generate knowledge rather than simply receive knowledge Interact with other students and class instructor	Use visual, image and other media to present complex ideas 	Short video on ANOVA topic Each group member identify solution for a small part of Accompanied comprehension question and discussion -how important concept being applied -how important concepts are related Teach other group members your solution Class instructors facilitate for class sharing
Constructive 	Making meaning from the learned concepts Solving problems using logical structure Breakdown problem into components	Use of concept map and worked example to present links between ideas 	Classification of Categorical data analysis into three types using concept map Procedure and worked example: Solving goodness-of-fit test Solving homogeneity test Solving independent test p-value, rejection region, chi square table reference, degrees of freedom, expected observation

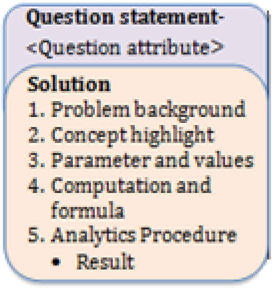
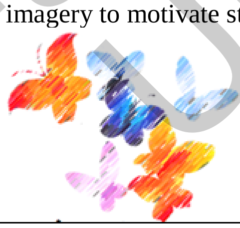
			
Collaborative 	students team together to explore a significant question or create a meaningful project	Encourage students to interact using visual imagery 	Cooperate with other students to Share ideas of new learned concepts example in lecture session Interact and teach the applied concepts Brainstorm to identify suitable project topic Collaborate to develop solution Discuss to compare solution
Authentic 	Exposed to real-life issues, problems and applications Learning by doing	Encourage students to present their understanding and meaning using visual imagery 	Conduct Group Project by presenting data analysis that answer certain theme such as water, Propose solution and present information using visualisation Provide vizz n video and Share with communities
Intentional 	Self motivation by engaging in persisted learning effort Achievement in knowledge and skills	Appealing visual and imagery to motivate students 	Advance organizer , concept map to enhance motivation to explore the topic Worked example to develop problem solving skills Kahoot quizzes, assignment to identify achievement

FIGURE 2. Embed meaningful learning in module

Visual cognitive support is among the proposed solutions for current scenario and issues in data analytic learning. Meaningful learning encourages cognitive visual tools to be used in classes to organize knowledge by linking new information with existing concepts in strong cognitive structure [44],[45]. To provide the support needed by students in their learning, specific scaffolding is offered to serve as guidance in developing better problem solving skills and knowledge construction [46]-[48].

In-depth understanding and concept integration are the main issues in data analytics learning and problem solving (Mulder et al. 2014). In order to help students gain meaningful learning and retain their knowledge, meaningful reception learning theory demonstrates advance organizer and concept map as among cognitive tools by linking new information with existing concepts in strong cognitive structure (David P Ausubel & Fitzgerald 1961). Meaningful learning strategies consider active, collaborative, and constructive to be embedded in the learning model.

Although this strategy has been adopted in previous research, the detailed implementation of these strategies in data analytics teaching and learning has not discussed. Hence, the analysis of literature has determined data analytics learning attributes and has designed scaffolding model for data analytics learning and problem solving using the recommended meaningful learning strategies.

This study offers visual framework as a compilation of all required ideas, concepts, examples, scenarios, as a structured and organized material to provide the support needed by students in data analytics learning. Three types of instructional design as visual cognitive support to build strong understanding structure i.e. active, collaborative and constructive are based on meaningful reception learning theory. The cognitive visual support model aims to assist instructors in developing better problem-based learning materials in their assignments and for providing a instructional assistance for students building their knowledge and problem-solving skills.

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