Final personal report

Converting abstract organic chemistry to a sensory 3-D experience

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1. Aim

The current generation of students is open to flexible approaches to learning, but they tend to suffer from "cognitive overload and conceptual and navigational disorientation" when they are introduced to a variety of information and abstract concepts that are unrelated, and complex with respect to knowledge structure (Gavrilova Alsufyev Grinberg and Mailov (2017:345). They are unable to form a meaningful pattern of the combination of knowledge to which they are introduced and they then struggle with memory retrieval. Students with only limited knowledge and understanding do not have the ability to organise the subject content for retention in long-term memory (Wang Peng Cheng Zhou & Liu, 2011:28). Effective communication within the learning environment is therefore the main aspect to consider in ensuring student success.

Previous researchers have investigated the integration and visualisation of major knowledge concepts, and the application of the insight gained through these studies to structuring curriculum design, learning theories and learning assessment (Renaud & Van Biljon, 2017). The aim of this study is to convert abstract organic chemistry concepts in Culinary Studies and Nutrition I into a sensory three-dimensional (3-D) experience and to map the basic concepts for better knowledge retention and retrieval. By demonstrating the influences of visual information on a presentation, the quality of students' knowledge-formation processes in Culinary Studies and Nutrition I were enhanced.
Unlike other studies in related fields, this study intended to depart from traditional educational practice by integrating visual concepts in each module as part of the whole concept of Culinary Studies and Nutrition I. Students had to participate in constructing knowledge maps, and were given the opportunity to build their own structures and understanding through integration to form the basis for future learning of Culinary Studies and Nutrition I concepts.

The project aimed to address these issues through the following objectives:

1. Developing a better understanding of the teaching and learning activities of Culinary Studies and Nutrition I prior to the design and implementation of knowledge visualisation.
2. Identifying the students' need for and experience of knowledge visualisation in Culinary Studies and Nutrition I as required for education.
3. Designing small interventions in a module in Culinary Studies and Nutrition I informed by design principles derived from both the literature and from empirical data obtained during interviews.
4. Implementing the small interventions in the Culinary Studies and Nutrition I context.
5. Refining and assessing the Culinary Studies and Nutrition I modules based on the results of the interventions.

6. Developing some suggestions for theory, practice, teaching education and curriculum design based on the results obtained.

2. Background and motivation

As knowledge of the world expands on a vast scale, researchers try to understand learning processes in order to sustain the science and development of education. There has been a paradigm shift due to basic changes in epistemology (Maimon, 2012:49). Time is generally becoming more limited; the quantity of information is growing; and the transfer of knowledge is becoming more complex (Meyer, 2010:23). Traditional ways of communicating are no longer sufficient. The basis of people's image of the world contains not only concepts, but also semantic images created with the help of visual thinking (Makarova Makarova & Varaksa, 2017:65).

Knowledge visualisation is a new field that is enjoying increased attention from both researchers and the private sector (Renaud & Van Biljon, 2017:1). Eppler and Burkhard were the first to define knowledge visualisation as "the use of visual representations to improve the creation and transfer of knowledge between at least two people" (Eppler, 2004:551). Renaud and Van Biljon (2017:5) refined the definition as "the use of graphical means to communicate experience, insight and potential knowledge in context, and to do so with integrity". They further explained that "such means should be flexible enough to accommodate changing insights, and facilitate conversations. Such representations facilitate and expedite the creation and transfer of knowledge between people by improving and promoting knowledge processing and comprehension, using familiar concepts where possible".

The use of knowledge visualisation in education has been supported by a number of researchers (Kostromina & Ginedykh, 2015; Makarova *et al.*, 2017; Wang *et al.*, 2011). Knowledge visualisation is based on a "mental image as object of learning" and indicates the level of accessibility and clarity of these images for subject content. The most important principle of learning to consider is the principle of clarity (Makarova *et al.*, 2017:67). Knowledge visualisation should be connected to metacognition, but students neglect many cognitive phenomena during lectures, with the result that they are unable to observe their learning and success in advance, or to control their comprehension and learning (Ursyn, 2016:1).

According to Ursyn (2016:1), the ways of cognitive thinking and learning are changing along with the availability of instructional technology and technological improvements. Visualising abstract relationships will assist in decreasing cognitive load and increasing processing abilities (Meyer, 2010:24), although the ways of being creative or solving a problem remain the same. The process of learning depends on how conscious and curious the mind is when encountering new information in a nonphysical manner, based on the functioning and physiology of the brain. The information is arranged through mental transformation, thus forming images in the brain. When external signals such as sound, shape, colour or motion are added to the experience, the information conveys meaning (Ursyn, 2016:2).

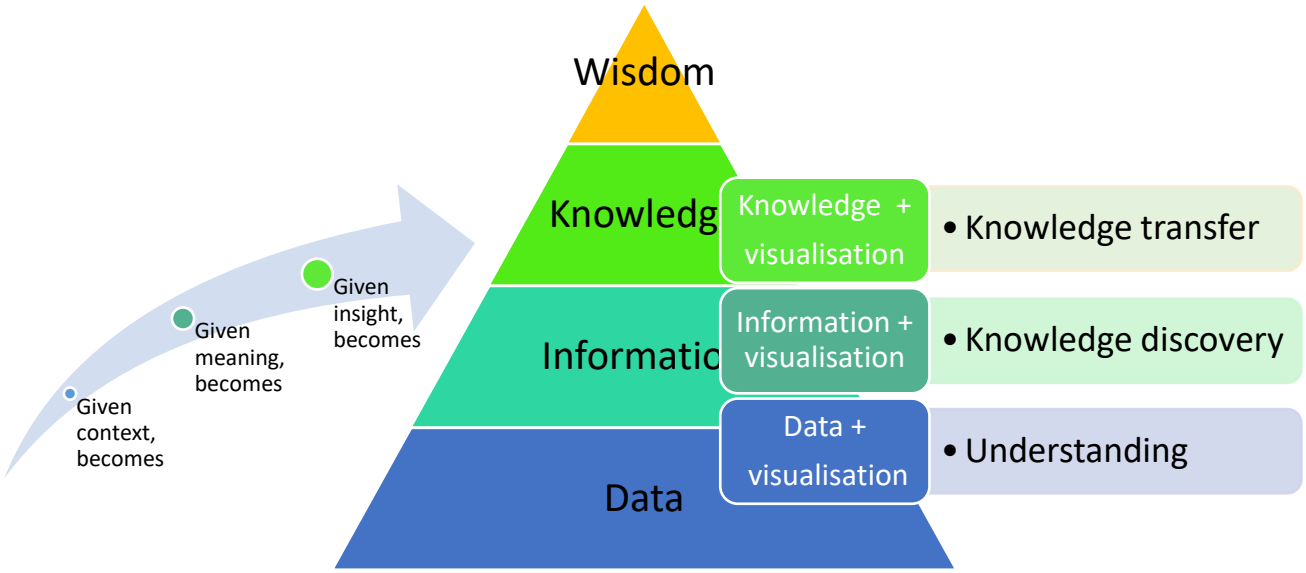

Figure 1: Data, information, knowledge, wisdom model (DIKW) (Renaud & Van Biljon, 2017)

As seen in Figure 1 data or new concepts are introduced to students. In order for understanding to develop, and given the context of the subject content, the educator should catch students' attention with visualisation in order to open their minds to form a "mental representation and image" of the information as a formal abstract concept that is seen as part of a process (Ursyn, 2016:1). The context of the knowledge is illustrated to make students aware of the importance of the knowledge and to give it meaning within the field of study. This ensures that students "plan their cognitive activities, implement metacognitive strategies into learning process, comprehend, memorize, monitor and correct errors, assess progress and also evaluate their results" (Makarova *et al.*, 2017). Knowledge visualisation thus provides the big picture of the lecture, ensures knowledge transfer and gives insight into the subject and its practical application (Renaud & Van Biljon, 2017).

Previous research in education and specific science-related fields (Evagorou Erduran & Mäntylä, 2015; Makarova *et al.*, 2017) suggests that the emphasis should be on cognitive understanding and that the products of science should be used as visual tools for understanding the content, study process and results of learning.

The challenge is to identify tools and methods that support the visualisation and usage of a specific problem or course content (Skaaf Jahn Tahar Kücherer Winter & Paech, 2016:349). The most common visualisation tools used in various contexts for different target groups and purposes include sketches, maps, diagrams, images, objects, interactive visualisation and visions (Meyer, 2010:26). The use of different forms of visualisation, especially visual images, sounds, movements, touch, taste and smell (sensory field), assists in creating knowledge and understanding of the concepts being introduced (Makarova *et al.*, 2017:65). In this way, vast and complex information can be remembered with insight (Ursyn, 2018:1), external knowledge can be shared with others, and an outline of the "bigger picture of the field of interest" can be visualised (Meyer, 2010:24).

In order to understand how knowledge is created in the classroom and how the processes relate to social interaction, certain learning theories will assist in designing

the learning process. Cognitivism and constructivism are the major learning theories proposed for this form of learning. During cognitivism information is being transformed into knowledge discovery with the assistance of knowledge visualisation artefacts to ensure problem solving at the end of the lecture (Meyer, 2010:26). Constructivism is the most important added theory to this study, because learning is seen as an "active process in which students construct new ideas or concepts based upon their current/past knowledge. Therefore the student has to create the knowledge based on his own experience" (Burkhard, 2005:24; Meyer, 2010:26).

Hospitality is a diverse industry with a wide scope of integrated subject content (CATHSSETA, 2017). Employment in the hospitality industry requires students to gain knowledge in subject content that entails both structural theoretical and practical training. These go hand in hand, and each has its own importance (Scholarship-positions, 2013). Hospitality Management students should develop the ability to understand theoretical concepts as well as a deeper appreciation of these concepts through applying them in practice.

TUT students in Culinary Studies and Nutrition I have difficulty in understanding basic abstract organic chemistry concepts and putting these into practice. The students encounter the subject content for the first time at university. Even if they studied basic organic chemistry in Life Sciences for their National Senior Certificate, they struggle to visualise the concepts and apply them in practice. They tend to study each module as a separate unit without relating it to the subject content of other Culinary Studies and Nutrition modules. The researcher tried using various different methods to assist students to understand and convert their knowledge into simple concepts, but there still seem to be gaps in extending the knowledge into practice, which impact negatively on students' success rate.

It is evident that there is a need to develop ways for students to understand the abstract organic chemistry concepts in Culinary Studies and Nutrition. There is also a need to incorporate knowledge visualisation in order to provide an anchor for knowledge retrieval and to ensure a real-world experience in the classroom.

3. Methodology

Design based research (DBR) is the most applicable research method for addressing this challenge. This emerging research method for educational enquiries can stand alone as an independent paradigm (Abdallah & Wegerif, 2014). As mentioned by Herrington McKenney Reeves and Oliver (2007:4089), DBR assists in developing learning theories and targets the improvement of educational practices.

A DBR methodology based on pragmatic epistemology were developed and used as the main research paradigm informing the design of this study. The research design consisted of a flexible three-stage research framework as illustrated in Figure 2 below.

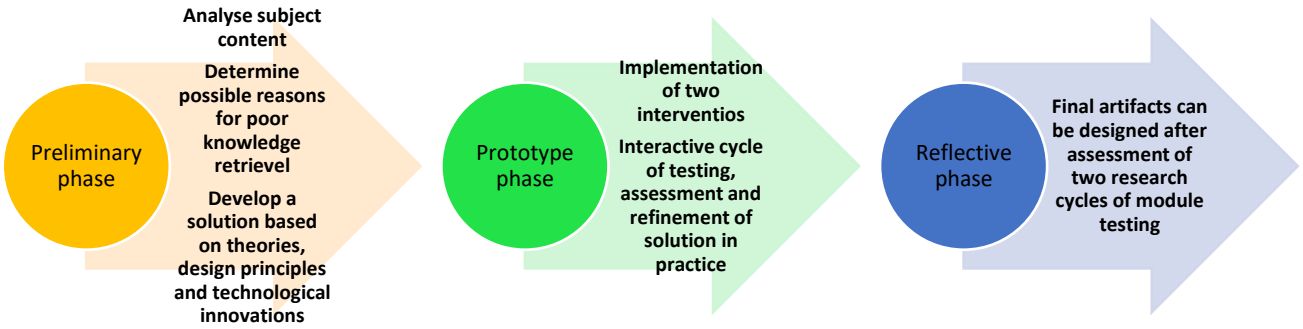

Figure 2: Three stage research framework

Twenty Culinary Studies and Nutrition I students from Tshwane University of Technology were recruited in class from a total of 191 students as voluntary participants in the focus groups in both the preliminary and prototype phases. Ten new first years and ten repeaters took part in the focus groups with consent after explaining the purpose of the study in class.

The study involved students in an education environment. Therefore the researcher considered procedures that are ethically correct and basic codes of ethics (Research Ethics Review Checklist, 2007(Jenning, 2001:98). Informed consent was obtained with clear information on the goal of the investigation, the procedures were followed, credibility of the researcher and the advantages of the studies were clearly stated (De Vos Strydom & Delport, 2005:59). During the study all the parties involved (support staff and respondents) were treated with respect, dignity, courtesy and their privacy was respected. Due to the inclusion of culture in the study, the researcher considered cultural sensitivity of the respondents and respected their human rights, and addressed the questionnaire anonymously with respect. (Hoffmann, 2010:6). (Ethical clearance number: REC/2018/12/006)

The researcher met the participants over a period of eight weeks at a scheduled time in a private lecture room at the TUT Department of Hospitality Management. The students were divided in three groups for the focus group discussions. The researcher used a co-lecturer for the interviews in the same field of study, and well informed on the purpose of the study. In this way, their participation would remain anonymous and their contributions were treated confidentially.

The preliminary phase focused on the students' contextual understanding of the subject context, whereas the prototype phase emphasised the students' responses to the lecture with implemented interventions. After presenting the new intervention in class, the same focus group was used to assess the implementation of the intervention in class. In the assessment or reflective phase, the quality of integration of the educational information was tested in a formative assessment of all Culinary Studies and Nutrition I students (n=191). The data from the focus group (n=20) was transcribed and coded, and sequential analysis conducted. The interventions were introduced to support staff members. Their comments and suggestions were also be considered.

4. Findings

The main objective during the preliminary phase was to develop better understanding of the teaching and learning activities in Culinary Studies and Nutrition I prior to the design and implementation of knowledge visualisation. The researcher also identified the students' need for and experience of knowledge visualisation in Culinary Studies and Nutrition I as required for education.

The focus group responses were analysed, and the responses were grouped according to what students like during a lecture with regard to the teaching method, teaching skills, teaching material used and means of communication. The researcher followed more than one teaching strategy (interactive whiteboard, incorporating different technology and share of student personal experiences) with the aim of transferring knowledge. The students expressed strong preference for the visual display of practical examples in the form of slides. In relation to teaching material, the students commented that it was very convenient to have access to learning resources (slides and previous tests) on e-tutor in advance of a lecture. The use of mnemonic devices, learning through experience, drawings, pictures and visual examples simplified concepts and learning. At the same time, the researcher's verbal skills, speaking loudly enough, keeping the students' attention, being active, interacting with students, allowing them to participate in class, and keeping them excited and attentive contributes to learning and ease of understanding. In order to understand and develop insight into the context of the subject content, the researcher applied cognitivism theory in relation to transforming information into knowledge, as used by other researchers, for example Meyer (2010). It was noted that students experience barriers in giving meaning to knowledge and being able to answer questions with insight in tests. Thus, the success rate is unsatisfactory, and students' uncertainty about writing tests was noted. Students tend to believe that they will be able to understand the subject content by reading the slides on their own and studying previous tests or examination papers. However, class interaction and simplifying of new knowledge are necessary to give meaning and insight into subject content.

The researcher concluded that giving meaning to knowledge transfer and knowledge insight is lacking. There seemed to be an assumption that students' attitudes and intentions would improve when knowledge transfer and insight into the subject content could be used during assessment and real-life situations. The introduction of constructivism theory, as investigated by other researchers, would therefore be applicable to this study. Learning is seen as an "active process in which students construct new ideas or concepts based upon their current/past knowledge. Therefore the student has to create the knowledge based on his own experience" (Burkhard, 2005; Meyer, 2010). In order to devise solutions to the problem of facilitating knowledge transfer and creating insight based on this theory, the researcher propose the use of visual representations. This approach is supported by several previous education studies (Makarova *et al.*, 2017; Meyer, 2010; Renaud & Van Biljon, 2017; Ursyn, 2018).

The prototype phase was introduced by designing small interventions in a module in Culinary Studies and Nutrition I, informed by design principles derived from both the literature and from empirical data obtained during the previous phase. The researcher used practical examples during the lecture and structured mind maps at end of the lecture to explain the subject content. At the end of the lecture, the students took part in compiling a mind map as a summary of the content of the lecture. A short class assessment was done in which the students could use the mind map as a guide to determine whether they understood the content and had insight into retrieving knowledge on the subject matter.

After class, a second focus group discussion was conducted with the same students in which they gave feedback on the interventions. The students expressed their perceptions of the interventions. They reacted especially positively to the adapted teaching method and acknowledged it as an improved way of teaching, contributing to understanding the subject content, and preparing and recalling subject content for assessment. A higher pass rate was noted after assessment being done on the lecture that included the interventions. The interventions also gave students a better understanding of the basic theoretical concepts when implemented in practical classes. The fact that the students are part of the class environment helps to prevent confusion and keep them focused. One of the students mentioned that the alternative teaching method was new, and that given the different ways in which students study, this simplified approach would help them to remember and understand complex concepts.

The students expressed a strong preference for visualised knowledge examples, as depicted in the picture. Simplifying the subject content contributed to understanding the concepts and gave the students a clear picture of the subject content. This resulted in easier studying and recall of the content during preparation for assessment. Thus, the students not only understood the work, but also gained insight into the subject content and meaning as seen in Figure 3 & 4.

Figure 3 & 4: Examples of knowledge visualisation

In relation to the compilation of a mind map (as seen in Figure 5 & 6) at the end of the lecture, the students commented that this gave them an opportunity to participate in learning and make the content their own. Asking questions and setting the headings and subheadings of the lecture helped in drawing the summary of the subject content in a clear and readily understandable way. Students gained confidence by using the mind map as a guideline during the class test to recall the subject content and apply their knowledge and understanding. After class, the students could use this mind map

as “a one page picture” of the most important content in order to study in an orderly manner.

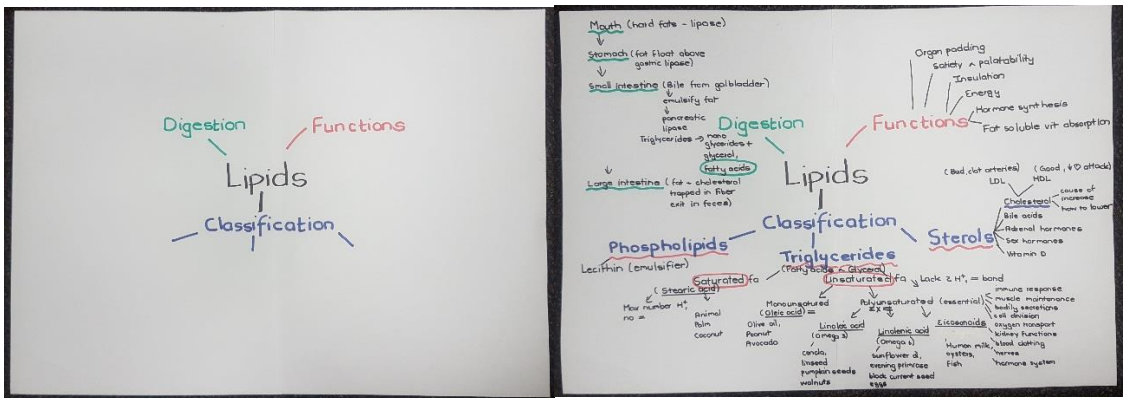

Figure 5 & 6: Flow of mind map

5. Discussion

The preliminary phase resulted in the application of knowledge visualisation in a lecture as an effective way for current modern students to digest educational information, develop understanding, give meaning to the content and gain insight into the subject and its practical application. Forming a “mental presentation and image” of the information as a formal concept guides students on the importance of the knowledge and gives meaning within the field of study. In this way, cognitive information is transformed into knowledge discovery to ensure problem solving at the end of the lecture. The use of knowledge visualisation made the learning an “active process” in which the students participated and could create their own knowledge background.

The two interventions – practical examples and mind maps – have a very specific role in relation to educational information, contributing to further use of this information in determining the effectiveness of knowledge transfer. In the prototype phase, the students suggested that this approach should be used in all Culinary Studies and Nutrition I lectures and rolled out in other subjects. As part of the reflective phase, the researcher presented the effective use of knowledge visualisation interventions in the classroom to peers in the field of Hospitality, and plans to present it to other institutions. It is imperative to understand that there are a vast number of possible knowledge visualisation methods, and it might be unrealistic to expect other researchers to use the same sort of visualisations in their lecture presentation. The critical issues are that knowledge visualisation should form the basis of knowledge transfer and should be presented in such a way as to simplify the content, and that it should ensure that students gain insight into knowledge based on their own experience.

The ways of cognitive thinking and learning as well as instructional technologies are changing, but the need for creativity, problem solving and understanding basic concepts remains the same. Therefore, the main purpose of the study was to incorporate certain learning theories such as cognitivism and constructivism to provide the lecturer with new tools in the development and use of knowledge and enhancement of visual literacy. By introducing knowledge visualisation artefacts, the students discovered more knowledge, which assisted them in problem solving at the

end of the lecture. The addition of a summary in the form of a mind map created the opportunity for students to participate in the learning process by breaking complex concepts down into separate parts. These findings form the basis for future investigation into using more knowledge visualisation artefacts and exploring their influence on reducing cognitive load and refining the learning process.

In the future, the researcher intends to study the use of knowledge visualisation in practical classes to enhance their effectiveness and to support the transfer of knowledge in the field of food and nutrition. It is further suggested that curriculum materials should be designed for a learning environment that supports interactive learning in order for students to participate in the practice of visualisation, thus developing their understanding and interpretation of knowledge. The implications for lecturers would include the introduction of professional development programmes to emphasise the implementation of visual representations in the classroom as part of the learning experience.

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