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ABSTRACT

This paper describes the first stage of a 4-year research project on the design, development and use of Web-based digital learning material for food chemistry education. The paper discusses design guidelines, based on principles that were selected from theories on learning and instruction, and illustrates in detail how these guidelines were used for the design and implementation of digital learning objects (LO). Six cases, a set of presentational LO and a dozen interactive exercises have been designed, developed, implemented, and imported in different learning environments. The design guidelines proved to be useful during the design process. The digital learning material has been evaluated positively by students and lecturers. The material forms now a set of inspiring examples for food chemistry in higher education. (Contains 10 references, 3 tables, and 2 figures.) (Author)

Design Guidelines for Digital Learning Material for Food Chemistry Education

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Abstract

This paper describes the first stage of a four year research project on the design, development and use of web based digital learning material for food chemistry education. The paper discusses design guidelines, based on principles that were selected from theories on learning and instruction, and illustrates in detail how these guidelines were used for the design and implementation of digital learning objects (LO).

Six cases, a set of presentational LO and a dozen interactive exercises have been designed, developed, implemented, and imported in different learning environments. The design guidelines proved to be useful during the design process. The digital learning material has been evaluated positively by students and lecturers. The material forms now a set of inspiring examples for food chemistry in higher education.

Introduction

The Food and Biotechnology (FBT) programme is a research programme on design of digital learning material. The programme was initiated at Wageningen University in September 2000 and currently counts 5 large projects. The digital learning objects (LO) that are developed within the FBT programme should meet the following requirements. First, the quality of the learning material must be considered highly satisfactory by experts in the respective fields as well as by students. Second, it must be possible to manage the LO with the mainstream Learning (Content) Management Systems (LMS). Third, the LO must be useful in a wide range of different instructional settings in higher education. Finally, the development costs for one credit point (one weeks study) material should be within the 60.000 $ (US).

Within the FBT programme a four year research project on the design, development and use of web based digital learning material for food chemistry education is carried out. Food chemistry is a disciplinary science, which masters and generates knowledge and insight mainly related to a) components of food, b) (bio)chemical reactions occurring in food, c) effect of treatments on (bio)chemical reactions and d) quality characteristics of food. The challenge of the project is to select and experience with design guidelines, taken from different disciplines in order to design effective LO for food chemistry education.

Theories on learning and instruction offer important clues to design effective learning material, including digital learning material. In particular there are good textbooks on course design and instructional design (Posner 1997, Smith 1993, Merriënboer 1997). Furthermore, there is much research on effectiveness of computer assisted learning. This research is mostly conducted in a laboratory context where a number of practical constraints can be ignored. On the other hand, much literature describes the use of digital learning material in practice. Nevertheless, practical detailed guidelines for the design of LO within realistic budgetary limits, which also satisfy technical and organisational constraints, are missing. In fact, there is a strong need for paradigm examples for specific scientific disciplines such as food chemistry.

The work presented in this paper describes the design guidelines for digital learning material for the introductory course Food Chemistry, which is a 4 credit point course for second year food technology students at Wageningen University. Material has been developed to support two, for this course, important learning objectives: acquisition, construction and retention of (declarative) food chemistry knowledge and a quantitative understanding of the relative importance of the chemical reactions occurring during food processing and storage.

The next section presents which pedagogical principles were selected. Section 3 describes how a set of digital LO have been designed and developed according to guidelines based in the selected principles. Section 4 gives the evaluation of the use of the LO by students and lecturers.

Selected Design Principles

From theories on learning and instruction, five principles were selected as the basis for every LO. This selection was based on three selection criteria. First, the selected principles are relatively insensitive to changes of educational or instructional concepts. Second, the need to reduce cognitive load was especially considered relevant for food chemistry, where the amount of detail is initially overwhelming for many students. Finally, the selection focuses on the strong points of digital material as compared with lecture notes. The principles are not completely mutually independent. The principles are:

a. Aim at optimisation of cognitive load

Cognitive load is the demand placed upon a person's cognitive abilities when performing a task. Effective training should reduce the cognitive load, since learning is typically constrained by limited processing capacity (Merriënboer 1997). Ignoring this principle will reduce the students' confidence. Digital learning material provides more possibilities to reduce cognitive load than lecture notes.

b. Aim at motivation of students

Motivated students learn better, faster, and more and also remember better (Schmidt 1998). According to the ARCS model (Keller 1988) instruction should capture the **A**ttention of the student, should be perceived as **R**elevant by the student, and should induce **C**onfidence and **S**atisfaction, to motivate students. From this principle many guidelines for the design of learning material can be derived. Digital material provides new options for motivation (Malone 1987).

c. Present information Just In Time (JIT)

Providing information just prior to application is a form of Just-in-Time Education (JiTEd)(Hudspeth 1992). An advantage of JiTEd based learning material is that the cost of learning is directly turned into benefit. JIT-information is also an instrument to prevent cognitive load as well as to motivate students.

It is important to be aware that students who work with digital material *expect* JIT presentation, since they *know* that JIT presentation is one of the strong points of digital material.

d. Visualise whenever possible:

There is much evidence suggesting that retention of knowledge will be enhanced when images accompany words (Denis 1994). Additionally, images will often increase quick understanding and reduce cognitive load (Anderson 1995, Larkin 1987). Lecture notes seldom take advantage of presentational formalisms other than printed text and formulas. Visualisation in digital material is ultimately cheaper than in lecture notes.

e. Activate whenever possible:

Students should be activated to elaborate on recently acquired declarative knowledge. Evidence is found that practice or elaboration on a subject strengthens the retention and the retrieval of the subject (Anderson 1995) as well as understanding. Better retention reduces cognitive load in later stages (Merriënboer 1997). Clearly information and communication technology offers much more possibilities to activate students than lecture notes.

Applying Design Principles within Food Chemistry Education

Digital material is designed according to several criteria, for instance the intended learning objectives and the requirements of the FBT programme, which are all considered as important to design successful digital learning material. The above mentioned design principles are translated into design guidelines that match with the other criteria. The design guidelines are therefore different for different kinds of digital learning material.

Presentational Learning Objects and Interactive Exercises

Presentational learning objects (presentational LO) and interactive exercises have been designed to support the acquisition, construction and retention of (declarative) food chemistry knowledge.

A typical example of presentational LO or interactive exercises is shown in the figures 1 and 2, which display two parts of one interactive exercise (see Demo Site). In this exercise students first have to look at the molecule of anthocyanin (a natural colorant). By moving the mouse pointer over a specific part of this molecule an explanation of a specific property pops up. Figure 1 shows the situation where the mouse pointer points at a place that is known to make a complex with a multiple charged metal ion. When students have read the information they can go to the exercise. This part, which is shown in figure 2, is based on the game mah-jong. The student has to click two pieces that belong together and press the OK-button. If the two belong together the pieces disappear. The goal of the game is to get rid off all pieces. The information linked to the molecule in the first part is related to the words on the pieces in the mah-jong game.

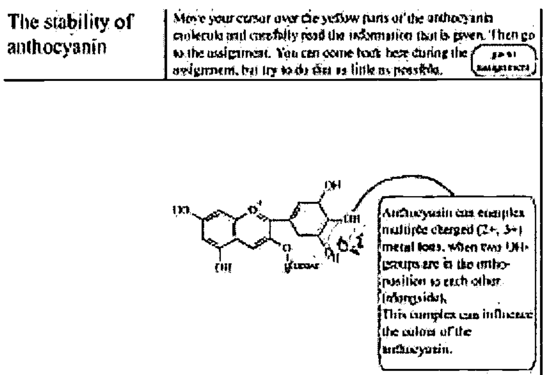

Figure 1: Information about properties that influence the stability of anthocyanin.

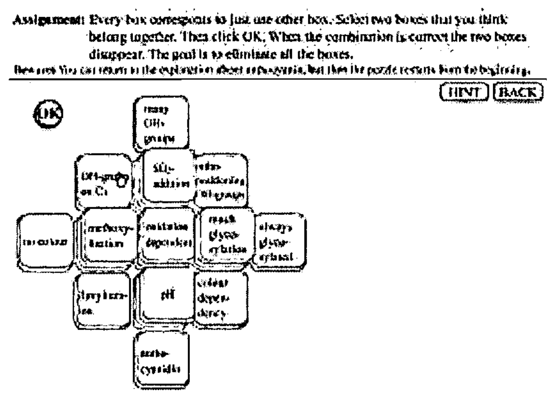

Figure 2: Exercise to elaborate on the previously acquired information.

The most important detailed design choices to design presentational LO and interactive questions, based on the guidelines listed in part 2, are listed in table 1.

Principles	Design guidelines
Minimisation of cognitive load	The LO and exercises should - Be small: it takes at most 30 minutes to go through the presented information. - Be independent: presented information is perfectly understandable on its own - Support acquisition or elaboration of one distinct knowledge structure - Use powerful key-symbols
Motivation of students	- Realise a large variation in the type of the LO - Incorporate games
JIT presentation	- Provide links to presentational LO in the interactive exercises - Present information which has to be used in actions in the same LO
Visualisation	- Consist of high impact visual components
Activation	- Induce active behaviour of the student

Table 1: Design guidelines specific for the design of presentational LO and interactive exercises

To minimise cognitive load the presentational LO and interactive exercises are small, complete and powerful. The LO are small since they are designed to take at most 30 minutes. In the case of the anthocyanin example, the whole exercise will approximately take 15 minutes. Second, the LO are independent and support the construction or the elaboration of a complete and distinct piece of knowledge. For instance, the example deals only with those properties of anthocyanin which are important for the stability of the molecule. The third way to minimise cognitive load is by using powerful key-symbols that explain the situation in a direct way. For instance, different parts in the molecule structure of anthocyanin (Fig. 1), the key-symbols, are highlighted (see Demo Site). Every student will understand that the information linked to a part belongs to that specific part of the molecule. This is essential to explain something without using words. The advantage of the natural relationship between (part of) an image and the meaning of that image is used in all LO and exercises.

To motivate the students, the range of different types of LO and exercises is large (see Demo Site). Different exercises are for example: a) choose the right option between two options, b) choose between several options, c) match propositions d) complete chemical reaction pathways by dragging molecules to the right place in the reaction, e) choose between different areas in a graph with different reaction rates, and f) complete the construction of a molecule by dragging the right component to each molecule. Examples of different presentational LO are: a) movies explaining or showing reactions, b) molecules that give information when clicking on it, and c) small, easy exercises providing additional information.

Another important tool to motivate students is by incorporating games (Malone 1987). The exercise in figure 1 and 2 is a typical example of a game. Several exercises have a game-like appearance.

JIT-presentation of information is mainly provided in two ways. First, the interactive exercises have links to corresponding presentational LO. In this way, students can easily look up information to answer a question or learn more about the subject. Second, like in the anthocyanin example, necessary information is presented within the LO.

Visualisation is an important part of the presentational LO and interactive exercises. Within these LO colour is used in a functional way, especially to highlight important elements. The visual LO vary from static pictures — for example a molecule or a photograph of a fruit — to animations and screen recordings — for example an animation of a chemical reaction in detail —. The use of text is minimised. Again the anthocyanin exercise is a good example.

The presentational LO and interactive exercises induce active behaviour. Both figures 1 and 2 show how students can be activated. In the first part of the exercise (Fig. 1) the student will only learn something about the molecule if (s)he points the mouse pointer at the molecule. The student is forced to pay attention to what (s)he sees and reads. In the second part of the exercise (Fig. 2) the student is activated to play a game and probably this activates the student to go back to the first part to study those parts (s)he didn't remember. In all presentational LO and exercises students are forced to do something: mouse-over actions, click the mouse, move objects, fill in numbers, answer short questions, play a game, etc.

Digital Cases

Digital cases have been designed to promote the transfer of knowledge of mathematics, reaction kinetics and reaction equilibrium, which students already acquired in previous courses, in order to be able to translate practical problems within Food Chemistry to arithmetical equations and to solve them. The intended learning outcome is a quantitative understanding of relative importance of reactions occurring during food processing and storage.

The digital cases are divided in a presenting and an activating part. The presenting part contains all necessary information about e.g. reaction kinetics and information about working with Excel. This information is structured in one place, which is denoted a library. The activating part exists of six different cases. Every case applies a certain concepts in the field of Food Chemistry, for example the hydrolyses of saccharose (sugar) in a fruit drink. On average, each case contains 10 guiding questions. The first questions (2 to 3) are introducing the subject, asking about basic knowledge necessary to understand the topic of the case. The following questions are mainly about making calculations or graphs, and they require for instance to fill in a (calculated) number or an interpretation of the calculation/graph. Calculations are assisted by the information in the library and by feedback and hints. The most important design guidelines for the digital cases, based on the principles in section 2, are listed in table 2.

The activating part within each case is built around a practical situation. For example, the student plays the role of a researcher who has the task to solve a problem in a company. The calculations on chemical reactions, kinetics, etc. are leading to a solution of the problem or a clarification of the situation, which shows the usefulness of the calculations.

Principles	Design Guidelines
Minimisation of Cognitive load	- Provide only necessary information - Minimise search for information
Motivation of students	- The student plays a role during the case - Show the usefulness of calculations - Give the student a feeling of independence
JIT presentation	- Provide hints/feedback/introductory questions - Provide movies on how to work with Excel

Table 2: Design guidelines specific for the design of the digital cases

The introductory questions have the objective to activate (make available) prior knowledge. The availability of much relevant prior knowledge improves the learning capacity (Schmidt 1998).

To minimise cognitive load, only necessary information that students need to calculate on reaction, like formulas, is provided in the library. Because students have to use some advanced tools of Excel, the library also contains information in the form of audio visual screen recordings. The students can put the information from the library immediately into practice, which is a form of JIT-presentation.

Cognitive load is also reduced by minimising the search for information, which is needed to solve a question within a case. Therefore, questions contain hyperlinks that point to specific information in the library. Also background information about food chemistry, for example, why a product turns brown during heating, is provided when needed. Especially the introductory questions refer to background information. Both the links and the background information are a form of JIT-presentation.

The information, the links to the information and the hints are applied in such a way that a student should be able to finish a case without the help of a teacher. The hints help students to work towards the solution. Students can ask for a hint themselves, but after submitting an incorrect answer a hint is given automatically. Also, after submitting an answer feedback on the answer is given. This will probably give the student the feeling that (s)he is able to solve the case by him or herself, which strengthens the student's self-confidence and satisfaction.

Evaluation of the Design Principles within Food Chemistry Education

The students used and judged the digital learning material during the time of the course. Table 3 gives some results from questionnaires students had to fill in after using the digital learning material. The results are categorised according to the principle they represent. Not all principles were evaluated, since some guidelines do not need to be judged by the students; these guidelines were just used by the designer.

It seems that the success of the digital cases is due to the JIT-presentation of information like hints, links to the theory, and feedback. Because of this information students seem to learn faster, to be more self-confident and to be more motivated to solve the questions.

The results of the questionnaires for presentational LO and exercises strengthen the belief that it is very well possible to provide knowledge by mainly using visuals accompanied by a minimum of textual parts, especially for explaining reactions or explaining intricate events in food chemistry. For food chemistry, visualisation of different aspects is a strong tool to help students understand and remember the sometimes intricate information.

For the designer, the guidelines, which are described according to theories on learning and instruction, supported the design of digital learning material based on theories rather than based on common sense. The guidelines keep the designer on the road during the project. Every piece of material that was designed and developed was judged to be parallel with the guidelines and principles. Although it is not easy to test if the principles are correctly implemented there has been no indication of the opposite.

The pedagogical principles seem to be translated successfully in guidelines that were used to design digital learning material. By this, a set guidelines based on general accepted principles are described that are useable in different educational settings within food chemistry and related settings.

Principle	Presentational LO and exercises
Cognitive load	- None of the objects give too much information at once - Time to finish each exercise ranged from 1 minute to 9 minutes (stdev = 60%) - The interactive exercises are clear: 95%
Motivation	- Exercises are useful: 86% - Students learned what was supposed: 86% - Students enjoyed the exercises: 86%
Visualisation	- Screen lay-out was judged positive - Objects that use more text than general are evaluated less positive by some students
Activation	- Activating parts, like clicking through an explanation of a chemical reaction or mouse-over effects, are judged useful
Principle	**Digital cases**
Cognitive load	- There is enough information provided: 100% - The links are useful: 100%
Motivation	- The difficulty of the cases was judged as good: 91% - Questions show the usefulness of the calculations: 91% - Questions give more insight in how to use the theory: 100% - Playing a role is motivational: 91% - Playing a role is useful: 100%
JIT presentation	- Introductory questions help to understand the cases: 100% - Movies about Excel are useful: 76% - Theory is useful: 95% - Hints are useful: 90% - Feedback was sufficient to carry out the cases: 86%

Table 3: Results from students' questionnaires.

Final Remarks

During the academic years 1999/2000 and 2000/2001 the digital LO were evaluated. Both students and lecturers judged the digital LO positive. The digital LO will now be used as an inspiration for faculty staff. Because of the independent character of the LO they can be imported in a range of different LMS such as Blackboard and Hyperwave ELS. The proof of the principle that it is possible to design and develop a rich body of LO for food chemistry, which satisfy the design criteria described in the introduction, is close at hand. Further research will be directed to articulation of design criteria for digital LO in food chemistry based on a match between intended learning outcomes of food chemistry courses and the possibilities and limitations of state of the art digital LO. This should be a first step towards a methodology of digital learning object design for food chemistry and to a handbook of best practices.

References

Anderson, J. R. (1995). *Learning and memory. An integrated approach.*, John Wiley & Sons, Inc.

Denis, M. (1994). *Image and cognition.* Paris, Presses Universitaires de France.

Hudspeth, D. R. (1992). Just-in-Time Education. *Educational technology.* 32 (6): 7-11.

Keller, J. M., Suzuki, K. (1988). Use of the ARCS motivation model in courseware design. *Instructional designs for microcomputer courseware.* D. H. Jonassen. Hillsdale, NJ, Lawrence Erlbaum.

Larkin, J., Simon, H.A. (1987). Why a Diagram is (Sometimes) Worth 10,000 Words. *Cognitive Science.* 11: 65-100.

Malone, T. W., Lepper, M.R. (1987). Making learning fun: a taxonomy of intrinsic motivations for learning. *Aptitude, learning, and instruction: conative and affective process analysis.* R. E. Snow, Farr, M.J. Hillsdale, Erlbaum: 223-253.

Merriënboer, J. J. G. v. (1997). *Training complex cognitive skills.* Englewood Cliffs, New Jersey, Educational Technology Publications.

Posner G.J., Rudnitsky A.N. (1997). *Course Design.* Fifth Edition. Longman Publishers USA New York

Schmidt, H. G. Moust, J.H.C. (1998). *Probleemgestuurd onderwijs. Praktijk en theorie.* Groningen, Wolters-Noordhoff.

Smith P.L.,Ragan T.J. (1993). *Instructional Design* MacMillan Publishing Company New York

Demo site: http://www.fbt.eitn.wau.nl/foodchemistry This site contains only a limited subset of all LO.

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