Animating the Intermediate: Design and Evaluation of a Dynamic Multimedia Format for the Aldol Reaction

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THEOREITCAL FRAMEWORK

Since the human eye is unable to observe processes at the submicroscopic level, visualisation has traditionally been of great importance in chemistry. However, the information-rich chemical formulae often cause novices to make insufficient links between the submicroscopic and symbolic levels [1]. As a result, they find it difficult to assess the reactivity of molecules and make correct mechanistic predictions. With the aim to find ways to foster learning in organic chemistry, this poster presents the design and evaluation of a dynamic multimedia learning environment for the aldol reaction (Fig. 1).

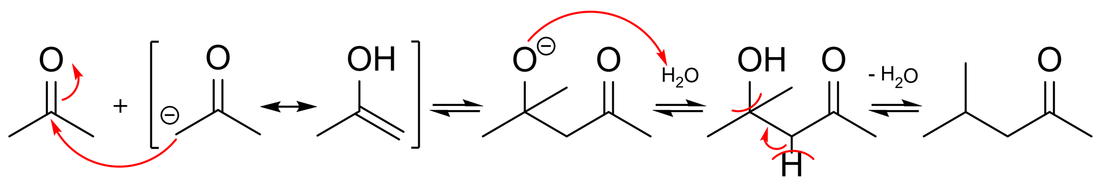

Fig. 1: Mechanism of the base-catalized aldol reaction for two acetone molecules

For the design of the instructional material, Mayer's Cognitive Theory of Multimedia Learning (CTML) was used, which describes learning in a simplified way as the taking in and processing of information in the working memory (Fig. 2) [2].

Every mental action carried out for that requires cognitive resources. If no more cognitive resources are available however, the so-called cognitive overload ensures that the learning process is terminated. Thus, all design principles to be derived from the CTML consequently aim at reducing the cognitive load and thus preventing a possible overload of the working memory. The contiguity principle, for example, states that related information should always be presented in temporal as well as spatial proximity to each other. For chemistry, this primarily places demands on structural formulae presented in reaction mechanisms. To further assist the connection of relevant information according to the cueing-principle, cues in the form of colour-codes can be used in the instructional material. Following the "thinking in pairs of opposites" typical for organic chemistry electron density was indicated with the help of colours as well as nucleophile and electrophile in the respective reaction steps [3]. To facilitate learning as much as possible, all information that was not strictly necessary for the moment was omitted. For this purpose, parts of the mechanism were temporarily blurred out so that attention could be focused solely on the relevant reactive centres (Fig. 3).

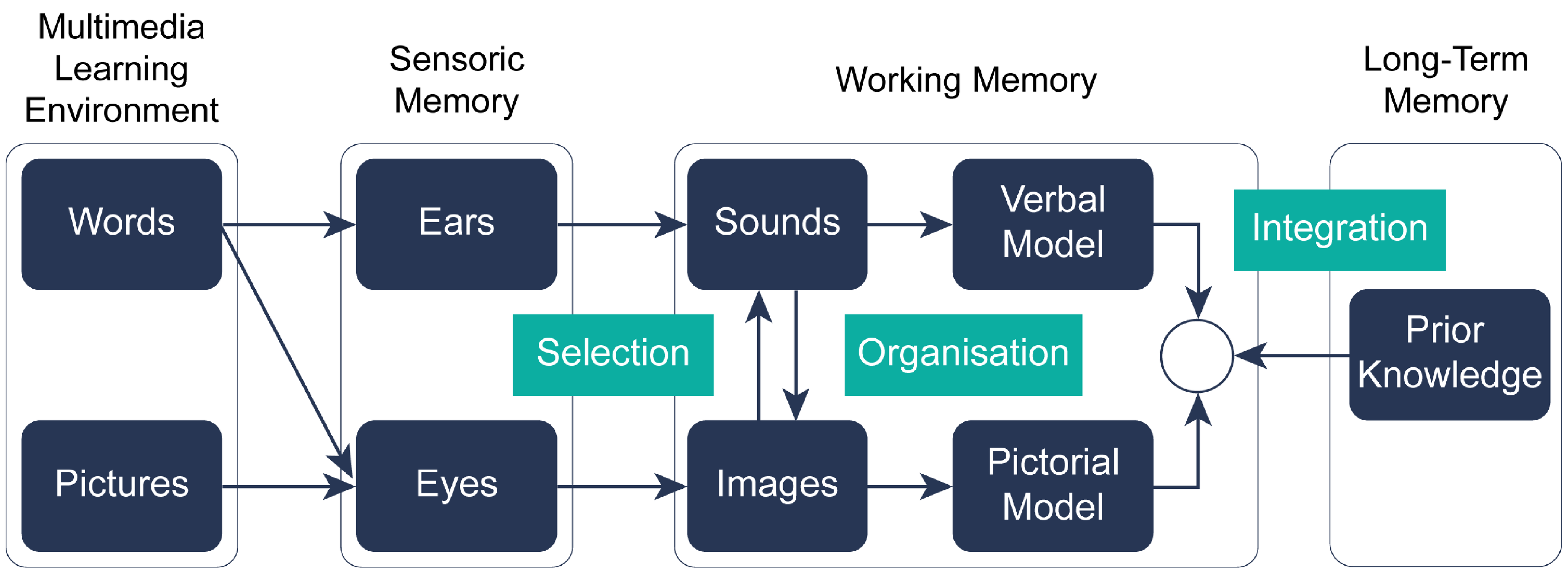

Fig. 2: Cognitive Theory of Multimedia Learning from Mayer [2]

SEGMENTATION

For segmentation of the instructional material the Four-Component Instructional Design Model (4C/ID) by Merrienboer and Kester was used [4]. First the learning content had to be divided with the aim to create small segments that can stand on their own without raising major contradictions. Following 4C/ID the aldol reaction was divided into 5 segments each which were then divided into 4 components seen in Fig. 3. Backbone of each segment were the learning tasks which did increase in difficulty while the given assistance was reduced successively. Before solving the tasks, students were provided with supportive information which can be seen as theory knowledge necessary to solve the tasks. While working on the tasks, students also received procedural information, which be considered as algorithmic knowledge for solving a specific task. At the end of each segment, the students got the opportunity to further exercise in the part-task practice.

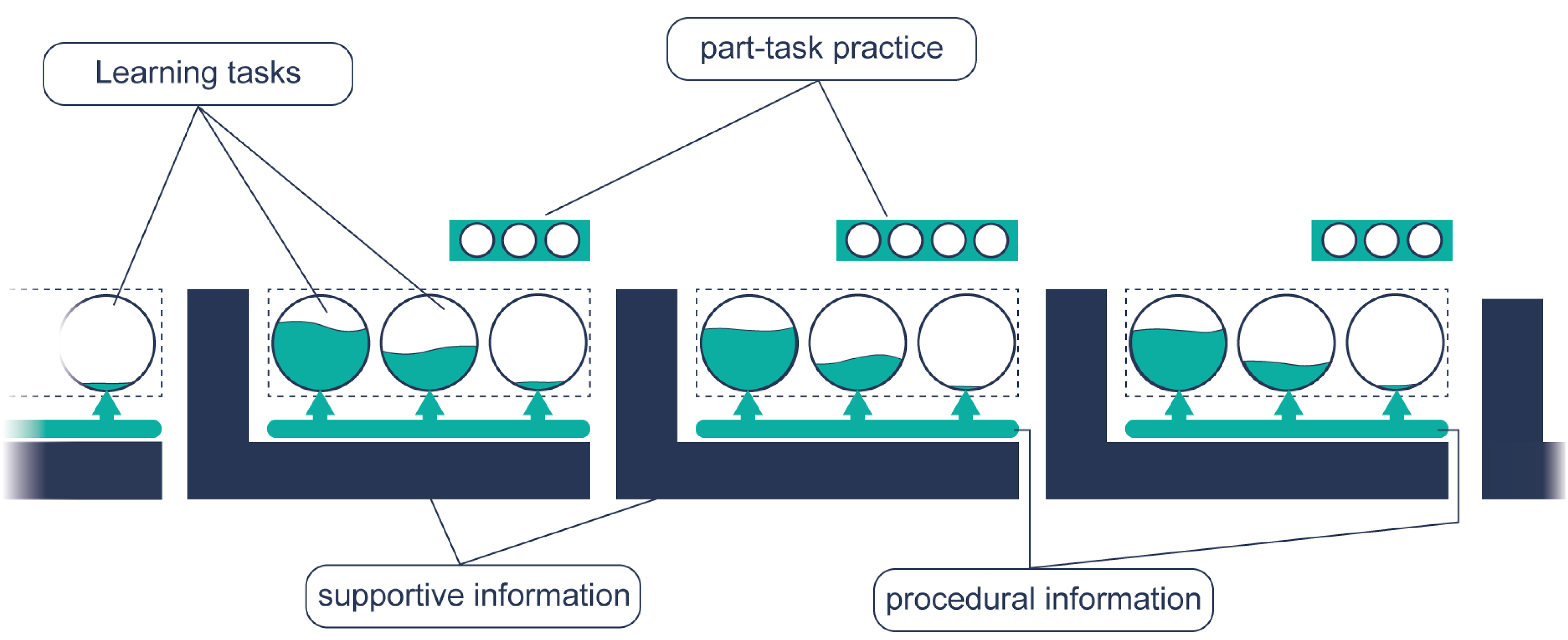

Fig. 3: Four-Component Instructional Design Model from Merrienboer and Kester [4]

EVALUATION

The instructional material was evaluated in a post-only design in which the intervention group received the instructional material described above. The control group received the textbook pendant as a treatment, which did not differ in content. All participants (N = 14) were undergraduate students who were randomly assigned to one of the groups and received the respective treatment over the course of 2 hours. Afterwards they were asked to fill out a questionnaire using a four-level Likert scale.

Both groups stated that they felt they had learned something about the aldol reaction after the treatment. Furthermore, they stated that they enjoyed the treatments and that they felt motivated during learning. The use of colours in the material was considered very useful by both groups, especially for the colouring of electrophile and nucleophile. However, differences in the perception of the mechanism were evident. The control group reported getting confused with nucleophile and electrophile more often then the intervention group. When asked whether they could comprehend the movements of the electron pairs within the mechanism the intervention group answered with "Strongly Agree" while the control group answered with "Agree". These findings were consistent with another item which asked if the students found it hard to follow the mechanism in general. Again, the control group stated that is was more difficult for them. The control group also reported that they had to pause their work more often and had to re-read sections more often. Interestingly, the control group stated that they found it easier to connect relevant information within the material.

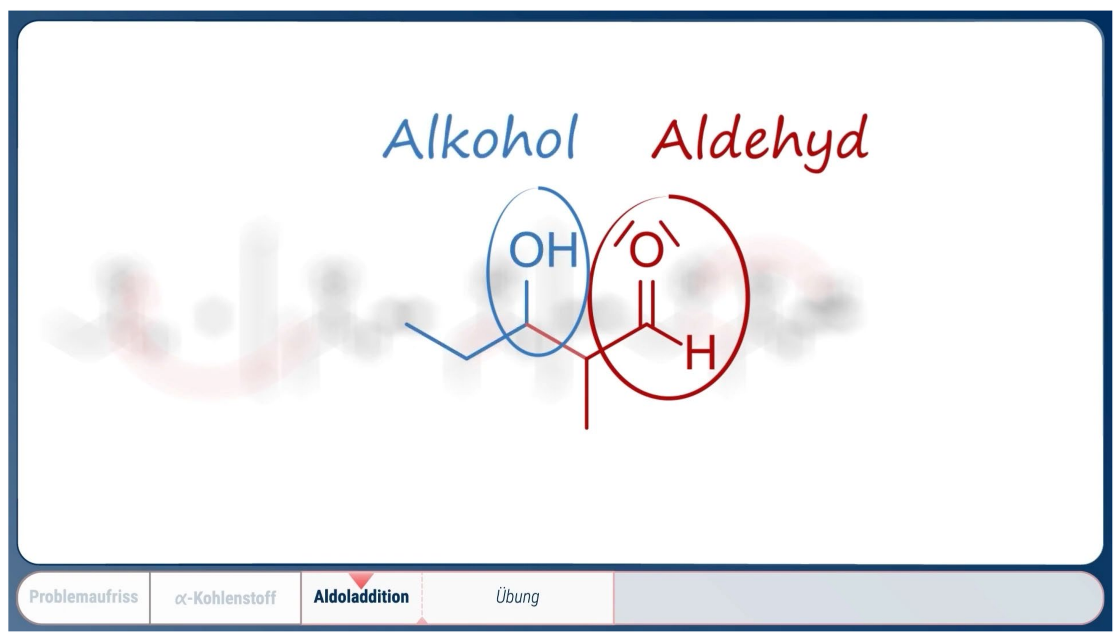

Fig. 4: Example from the instructional material for the aldol addition

OUTLOOK

The evaluation showed that the 4C/ID model as well as the CTML are eligible theoretical frameworks for planning multimedia learning environments in organic chemistry. The evaluation was mostly in favour of the multimedia material. Interesting findings were that although students form the intervention stated that they were able to follow the mechanisms better overall, the control group rated the static monomedia material better in terms of handling. The aim of the next study should be to investigate these finding quantitatively with a large sample size.

Literatur / References

[1] A. H. Johnstone "Macro- and micro-chemistry", School Science Review. **1982**, 64, 377-379. [2] R. E. Mayer "Cognitive Theory of Multimedia Learning", in: The Cambridge Handbook of Multimedia Learning. R. E. Mayer (Ed.), **2014**, New York, 43-71. [3] R: Demuth, B. Ralle, I. Parchmann "Basiskonzepte – eine Herausforderung für den Chemieunterricht", Chemkon. **2005**, 12(2), 55-60. [4] J. J. G. van Marrienboer, L. Kester "The Four-Componenten Instructional Design Model: Multimedia Principles in Environments for Complex Learning", in: The Cambridge Handbook of Multimedia Learning. R. E. Mayer (Ed.), **2014**, New York, 104-148.

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← Scan the QR-Code to see an excerpt of the dynamic multimedia format for the aldol reaction

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