DyKnow™

A Research Based Approach to Encouraging Effective Note-taking: Best Practices and Supporting Technologies

In recent years, the increased deployment of computer labs, laptop initiatives, and pen-based computers in both K-12 and higher education classroom settings has made it possible to provide more interactive and student-centered lectures and classroom presentations. Ideally, the use of these technologies should also support students as they engage in proven study techniques such as note-taking and note-review. This article explores previous research related to the benefits of note-taking and the methods that are used to facilitate effective note-taking, and then discusses DyKnow Vision™, a tool that can be used to enhance the note-taking experience as well as to foster an interactive classroom environment. In a recent survey of 81 students who had used DyKnow Vision in a total of 431 courses, 64 students (79%) indicated that there was "significant value" in the DyKnow Vision approach to note-taking while an additional 15 students (19%) rated the approach as having "moderate value". In total, 79 of the 81 students found value in using DyKnow Vision for note-taking.

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2 Previous Research into Note-taking

2.1 Why Take Notes?

According to an enormous body of research developed over the last quarter-century, useful note-taking provides two main benefits. First, note-taking serves as an encoding mechanism, allowing the learner to store information in a useful way by interpreting material and associating it with prior experiences. Second, note-taking provides a mechanism for external storage, allowing students to use their notes as a resource for later review. The following sections discuss research on each of these functions.

2.1.1 Encoding: Learning While Taking Notes

According to the "encoding" hypothesis, knowledge is stored in mental structures unique to every individual. When new information is learned, it is added to an existing "mental model". If the new information is novel enough, a new mental model is created. The structure of mental models is influenced by the way material is initially presented, as well as by the learner's own unique thought process and experiences with similar information in the past. Researchers believe that note-taking affects the way that models are created. Note-taking appears to help students to pay attention, develop individual ideas, and organize material better in their own minds (Einstein et al., 1985).

Effective note-taking appears to have a particularly positive impact on a student's ability to answer questions that require higher-level thinking. In a study of note-taking in science lectures, Peper and Mayer (1986) found that students who take notes perform better at critical thinking exercises and exercises that require transfer of knowledge to other areas, as compared to students who listen without taking notes. Another study showed that students who review their own notes after a class session also perform better then those who review notes created by others (Kenneth A. Kiewra et al., 1991). This is likely explained by the theory that students will recall conceptual information best when retrieval "cues" match those they formed when they first learned material. Providing possible support for this theory, an investigation of student notes indicated that students do not merely record factual information verbatim. Instead, diagrams, arrows, and other mechanisms are often used by students to record notes in a way that matches their own encoding mechanisms (Peper & Mayer, 1986).

The impact of active note-taking on factual recall is less uniform. In fact, some evidence shows that studying from notes provided by the instructor may be as good or better than using student-taken notes, especially for reviewing factual material (Kenneth A. Kiewra, 1985b). This is probably because student notes are often incomplete or inaccurate. On the other hand, when accurate note taking is achieved, it has proven to be an important factor in correctly absorbing factual information in many studies. In one of the studies most supportive of note-taking for factual recall, for example, students listened to a lecture while taking notes at their own discretion. After the lecture, the students took a recall test without being given any opportunity to review their notes. Even though no note-review was permitted, students had a 40% chance of recalling material which could be found in their notes, as compared to a 7% chance of recalling material that they did not record (Einstein et al., 1985). This appears to indicate that students retain more of the factual information they include in their notes as compared to information they do not record (Einstein et al., 1985).

The use of effective practices that help students create complete and useful notes will be discussed in section 3.2, "Facilitating Good Note-taking". Section 4 of this paper illustrates how software systems can be used to support these practices.

2.1.2 External Storage: Learning from Reading Notes

In addition to the benefit of allowing students to be actively involved with material during class, notes are often used as a way to record information for later review. In fact, the review process itself may be an opportunity for further encoding of information (Kenneth A. Kiewra, 1985a). Several researchers have demonstrated the effectiveness of studying from previously taken notes. In one

study, for example, students were given a recall test one week after taking notes on a lecture. Students who were allowed to review their notes prior to the test recalled four times as much information as those who were not allowed to review their notes (Einstein et al., 1985).

Similar results have been demonstrated in other settings. For example, in a study of undergraduate college students taking a performance test (consisting of cued recall, factual recognition, and transfer related questions) one week after being presented material, students who received notes to study performed dramatically better then those who received no notes. For the test questions that required transfer of knowledge to a new situation, students who studied outline notes that they took themselves earned almost twice as many points as those who did not review any notes. On a "cued recall" test which measured the retention of factual knowledge, students who were allowed to briefly study outline notes were able to record 21.09 important points (out of 121 possible topics) when asked to note all items recalled, while students who had no notes to study only recorded 2.82 items (Kenneth A. Kiewra et al., 1988).

2.1.3 Additional Issues to Keep in Mind Regarding Note-Taking

Students, particularly those at early ages, need guidance in order to take useful notes. For example, a study of fifth graders creating notebooks as part of a hands-on science curriculum determined that the type of notebook entries made by children is highly dependant on instructions given by teachers. Students recorded information (such as procedures and results) when specifically prompted by teachers, but did not record thoughtful reflection, interesting class discussions, or their own questions (Baxter et al., 2001). The authors conclude that notebooks can be used to facilitate learning, but only if the teacher explains what is expected from the students. Encouraging students to take notes of examples, discussions, and their own critical thinking processes and questions can help them to take more comprehensive and useful notes.

Even at the college level, not all students appear to have acquired good note-taking skills. In one study, successful students (who maintained a high GPA in college courses) appeared to be better able to distinguish highly important material from less important material, and overall noted more highly important items in their notes then did less successful students (Einstein et al., 1985). This indicates that not all students are equally adept at taking good notes. Suggestions for helping students take better notes are provided in the following section of this document.

2.2 Facilitating Good Note-taking

Research suggests many ways to encourage good note-taking by students. Although all of these techniques require fore-thought on the part of teachers, the impact on student learning may make these techniques well worth the effort. One method for helping students create a complete and useful set of notes is

the use of "guided notes". Guided notes are often presented as handouts that correspond to the instructor's teaching notes or slides. These guided notes are constructed with key pieces of content left out. Students may use the guided notes as a framework, filling in the missing pieces as class progresses. A large body of evidence shows that the use of some form of guided notes helps students to encode better, and also results in notes that are more useful for student review. For example, in a study of college-level psychology students, the use of guided notes was shown to significantly improve student note-taking. When visual aids (such as slides) and guided notes are both used, students record more critical points and more examples than in more traditional lecture formats. In one study, 60% of relevant examples are accurately noted by students using guided notes, while only 26% are recorded by students attending a lecture with slides, and a mere 13% of these examples are recorded by students who attend the lecture only (Austin et al., 2004). Similar results were noted in earlier studies across diverse groups of students, including high school students, incarcerated juveniles (aged 13-19), college-level students with learning disabilities, and mainstream high school and college students (Austin et al., 2004).

There are several ways to provide guided notes. One technique involves the use of "skeletal notes", which consist of an incomplete outline of the instructor's notes. Skeletal notes can be a good way to combine the full advantages of detailed, well-structured instructor notes with the encoding benefits that stem from taking and studying self-created notes (Kenneth A. Kiewra, 1985b). Research has shown that well-designed skeletal notes are more effective than free-form notes or complete instructor notes handed out before the class session (Hartley, 1976).

Skeletal notes usually take the form of the instructor's notes with details left out. However, there are other forms of guided notes that have proven even more successful in some settings. Most of these strategies use visual and/or spatial representations which help the student to understand and mentally organize concepts. For instance, linear outlines help organize the information by listing topics and related sub-topics in a way that indicates their relationship but leaves space for students to fill in details. Notes in the form of a matrix allow the learner to identify and understand relationships between and within categories of information(Kenneth A. Kiewra et al., 1988). Hierarchical diagrams allow students to understand the relationship between concepts by displaying them as a tree (Kenneth A. Kiewra & DuBois, 1992). Sequential representations, which use layout, arrows, and other graphical techniques, allow cause and effect or a sequence of events to be illustrated clearly (Kenneth A. Kiewra & DuBois, 1992). Graphical organizers use white-space and the placement of text to indicate relationships between concepts. Knowledge maps or concepts maps work similarly, using notes and lines to indicate the relationship between concepts. These visual representations can be used effectively when partially completed, allowing students to take some of their own notes while modeling an alternative strategy for note-taking (Katayama & Robinson, 2000).

Finally, a few minutes spent carefully introducing the material before presenting it, as well as providing time for students to work with material after it has been presented, can have great benefits. Advanced organizers (written summaries of what will be discussed) presented before a lesson can help learners to retain more factual information as well as come to a higher-level understanding of the relationship between concepts learned. Advanced organizers may be a simple list of topics or an outline of topics and sub-topics, or a matrix that presents a group of concepts with a complex relationship (Kenneth A. Kiewra & Mayer, 1997). Immediate review or testing of material following presentation appears to also strengthen associations made by the learner and aid in retention (Di Vesta & Gray, 1972). Practice or hands-on exercises may be engaging to students, as well as providing an additional mechanism to assist in encoding new material. These can be built into guided notes, by providing plenty of room for students to work out their own solutions and annotate them during discussion.

3 The Role of DyKnow Vision in Facilitating Note-taking

With the increasing availability of computers in K-12 and college classrooms in the United States, research related to computer-aided note-taking has become increasingly popular. In this section we focus on a software system known as DyKnow Vision, which is being used successfully in K-12 classrooms as well as higher-education institutions. DyKnow Vision can be used in traditional computer labs, or in any classroom with portable laptops, Tablet PCs, or other pen-based note-taking devices. Data indicates that students believe the system improves their ability to take notes and increases their confidence that they leave class with a well-organized and accurate set of notes for studying. Students frequently report that they believe they learn more in courses facilitated with DyKnow software.

Concerned that students spent most of their time and energy copying down notes rather than interacting with the material during a traditional lecture, Dr. Dave Berque, a Computer Science Professor at DePauw University, designed a prototype system to help students interact more directly with the teacher and the material during class. One objective of the system was to facilitate effective note taking, by allowing students to spend less time copying down complex diagrams and mechanically transcribing what the teacher was saying, while also helping students to avoid note-taking errors. Rather than eliminating student note-taking, the goal was to transform the nature of student note-taking from rote copying to higher level analysis. Students could annotate on top of or alongside the teacher's notes, allowing for the benefits of active note-taking (Berque, 2005). An enhanced and extended version of this software is now called DyKnow Vision.

DyKnow Vision allows teachers to use prepared class materials, or to design class material on the fly using a laptop computer, Tablet PC or other personal computing device. Regardless of whether materials are prepared in advance

or extemporaneously during class, DyKnow Vision allows the students and teacher to share them easily and naturally. For example, the teacher can extemporaneously draw sketches directly on the surface of a pen-based computer or electronic whiteboard. Alternatively, the teacher can use a keyboard to type material, and can import material (including graphics, PowerPoint slides, and live Web content) that was prepared ahead of time. All information sketched, typed, or imported by the teacher immediately appears on each student's display, where students can then use a keyboard, mouse, or stylus to annotate directly on top of the material, or within a private notes pane. While the software has many additional features, especially those that promote classroom interaction, a full description is beyond the scope of this paper (the interested reader is referred to www.dyknow.com). In the remainder of this paper we focus on the relationship of DyKnow to note-taking.

3.1 Using DyKnow to Support Effective Note-Taking

Because DyKnow software allows teachers to transmit notes for students to complete or annotate, it can provide the benefits that stem from allowing students to augment partial notes structured by the teacher, without many of the limitations associated with using paper-based guided notes. For example, while paper-based guided notes must be prepared in advance, guided notes delivered with DyKnow Vision can also include material that is developed extemporaneously during class (perhaps in response to a student question or comment). In addition, paper-based guided notes are most conveniently delivered to students in packets that cover one or more class periods. On the other hand, guided notes delivered with DyKnow Vision can be electronically released to students on a page by page basis. This helps students stay on task, and prevents them from looking ahead in the notes to find answers to questions that the teacher wants the students to grapple with during class.

Students see the value in the DyKnow Vision approach. In a recent survey of students who have used DyKnow Vision, 95% of students indicated that the use of DyKnow Vision software in the classroom provides a moderate or significant value in enhancing their understanding of material during class, and 98% indicated that they gained moderate or significant value by adding their own notes to teacher content (Berque, 2005).

DyKnow software is uniquely suited to the use of skeletal or partially completed notes for augmentation by students. Whether the teacher pre-prepares notes or creates them extemporaneously, it is easy for the teacher to accommodate student annotations. By adjusting the amount of material sent to students' own electronic notebooks, the teacher can allow students to benefit from interacting with the material during class time, without requiring them to frantically transcribe each item. Students may annotate directly on the teacher's notes, or add additional notes to a private notes area attached to each page the teacher

provides. Through use of the private notes pane as well as multiple "ink" and "highlighter" colors, students can easily distinguish personal notes from those the teacher or other students created. In the survey of computer science students using DyKnow Vision, 87% of students indicated that they sometimes or frequently use the highlighter and pen tools to emphasize material written by the teacher, while 93% use pen or keyboard to make further annotations on material presented by the teacher (Berque, 2005). According to a student in a another recent survey, "Being able to distinguish between what the teacher said and what I was thinking is a nice thing that is hard to reproduce in a [traditional] notebook"(Mitra-Kirtley, 2005).

Using DyKnow Vision, teachers can also provide complex diagrams or other visual aids, without fear that students will make errors in transcription or be so busy copying that they miss essential discussion of the illustrations. Survey results demonstrate that students especially appreciate this feature. One hundred percent of students indicated that use of DyKnow Vision has moderate or significant value in "providing an accurate set of notes", and 86% indicated that the use of the system eases the note-taking process by not forcing them to copy everything down. According to one student, "I think that it is sometimes a burden to take detailed notes- especially when involving complex graphs, tables, stats, etc. … [DyKnow Vision] would save time and provide more accurate and detailed notes- specifically graphs" (Berque, 2005). Students can also use the graphical features of DyKnow Vision to highlight important facts, connect concepts using arrows or lines, or sketch their own diagrams. Adding graphics or screen-captures of other applications is also easy for both students and teachers, allowing for a variety of graphical content to be included in the note books and further annotated.

DyKnow can also be very helpful to students who do not have fully developed note-taking skills, or who can not take their own notes well because of cognitive or other disabilities. Students who do not normally take notes benefit from having at least a framework to study from after class. According to one student, "I focus much more in DyKnow classes than I do in standard classes, and because I don't take notes often outside of DyKnow classes it gives me something to look back on when I really need it." (Berque, 2005)

Even more excitingly, DyKnow Vision can also be a useful tool in assisting students in developing good note-taking skills of their own. For example, a recent workshop for at-risk students used DyKnow Vision to teach students how to take better notes. As the workshop began, an instructor presented a mock class and the students took notes using DyKnow Vision. Next, the DyKnow Vision system was used to electronically collect the student notes, so that they could be displayed at the front of the room. A note-taking specialist then used the sample notes to stimulate a discussion about good note-taking strategies (Berque, 2005). The ability to collect student work, including student notes, allows instructors to provide constructive feedback for all students, including young students or those who need remedial

support. This is also a good way to monitor student use of new note-taking strategies being presented, such as the use of skeletal or matrix guided notes. If desired, teachers may even collect work anonymously, which can help reduce anxiety for some students.

3.2 Using DyKnow to support Useful Note Review

DyKnow notebooks from current and prior classes can be accessed at any time from any Internet-enabled computer. According to students surveyed, DyKnow notebooks have become an important resource for studying for exams, doing homework, or even referencing relevant material during subsequent lectures or subsequent courses. Notebooks are organized by class and date, and students can save notebooks with meaningful filenames. Many students appreciate the way DyKnow Vision allows them to keep all their course material together. According to a student video on DyKnow use in high school level classes, "Paper notes are often messy and unwieldy. It is difficult to keep notes together and organized... With DyKnow, students need not worry about loosing notes, as organization is made easy, and accessing older notes for review is painless" (Ritz, 2005).

As another advantage, DyKnow Vision notebooks provide a shared artifact that combines the structure and details provided by the teacher with each student's own guided notes and insights. This makes DyKnow notebooks a good source of material for review. The ability to continue interacting with the notebooks after class makes them an even more powerful study tool. Students may modify in-class notes or copy notes from multiple notebooks into a new, comprehensive set of notes while studying. The ability to augment notes outside of class time allows students to think through the material one more time. In a recent survey, 58% of students indicated that they sometimes or frequently add annotations to DyKnow notebooks while studying outside of class. One student commented "I like being able to access my notes universally from on or off campus, I like being able to access the DyKnow network from my own personal computer, and I enjoy being able to go over my notes and modify them endlessly" (Berque, 2005).

Paper notes are static documents that capture content rather than process. For example, imagine that a chemistry teacher wanted to explain an electrolysis experiment[1]. The teacher could draw several molecules on a black-board. Then, using an eraser, the teacher could break the bonds between the hydrogen and oxygen atoms and redraw the bonds, showing the new hydrogen and oxygen molecules created. The instructor might then wish to add another layer of complexity, showing how the experiment can be improved by adding a salt which ionizes in the water. In order to record this process in their paper-based note books, students will have to draw multiple pictures or risk losing part of the process that was shown.

[1] Electrolysis involves using a current to split water molecules, resulting in the creation of hydrogen and oxygen ions which recombine at electrodes to form hydrogen and oxygen molecules and can be collected in the form of gas bubbles

Notes taken with DyKnow Vision, on the other hand, capture process fully. Specifically, any page from a DyKnow Vision notebook can be replayed stroke by stroke. In the electrolysis example, students could replay the entire sequence of events shown by the teacher on the board. The replay capability includes all teacher content as well as student annotations, and therefore allows a student to review how diagrams and other content were developed during class. This means that teachers do not need to find videos or create complex animations prior to class. DyKnow Vision allows the instructor to draw a representation of a sequence of events on the fly, and feel assured that students can play the sequence back as many times as they like after class. DyKnow Vision even allows students to control the pace of replay, allowing them to explore details they may have missed during class.

Results of student surveys have demonstrated the value students place in using DyKnow Vision for note-review, including the value that stems from the ability to replay notes stroke-by-stoke. Eighty-seven percent of students surveyed indicated that they found moderate or significant enhancement in their understanding of material when reviewing notes created in DyKnow Vision. One student testified "I … immensely like the replay panel. It is really helpful when understanding some concepts taught in class" (Berque, 2005).

4 Conclusion

A review of the literature related student note-taking indicates that note-taking plays a key role in student learning. Further, the literature demonstrates that there are a number of ways to foster good note taking in students of all ages. Many of these techniques are based on providing students with a framework that they can use as a building block for their own notes. A tool such as DyKnow Vision can make it easier for a teacher to provide such a framework. This can encourage good note-taking practices, helping students to encode better during class time and to create notes which are more useful for later review. Students using the software for note-taking report additional benefits as well. These benefits include easy access to class notes, and the ability to replay notes stroke by stroke while reviewing after class.

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