Level 2 concept synthesis answers key

Concept mapping was developed as a method of displaying and organizing hierarchical knowledge structures. Using the new, multidimensional presentation software Prezi, we have developed a new teaching technique designed to incorporate higher-level skills in the cognitive domain. This tool, synthesis mapping, is a natural evolution of concept mapping, which uses installation for layered information within concepts. Prezi's zoom user interface allows the author of the presentation to use both depth and distance to show links between data, ideas, and concepts. Students in the Cancer Biology class created synthesis maps to illustrate their knowledge of tumorigenesis. Students used multiple organizational schemes to create their maps. We present an analysis of student work, placing special emphasis on the organization within student maps and how the organization of knowledge structures in student maps can reveal strengths and weaknesses in student understanding or instruction. We also provide a discussion on best practices for instructors who want to implement synthesis mapping in their classrooms. Experts within the field have rich, well-connected knowledge structures that allow them to quickly retrieve information and see unexpected links and patterns. On the other hand, beginners in the field have not yet formed these well-connected knowledge structures and can therefore see the information as a series of unrelated facts or as groups of facts within unrelated silos. According to key work As people learn, to develop competences in the field of investigation, students must: (a) have a deep basis of factual knowledge, (b) understand facts and ideas in the context of the conceptual framework, and (c) organize knowledge in ways that facilitate finding and application (National Research Council [NRC], 2000, p. 16). Thus, the focus of many college courses is the development of an organizational framework for students to help them establish a lasting understanding of the subject being studied (Khodor ir., 2004). When teaching a higher-level undergraduate degree, Cancer Biology, one of the authors (C.J.B.) noted students' difficulties with developing this type of organizational framework. Therefore, we have created a type of task, called a synthesis map, as a tool to help students within this course develop an explicitly defined organizational framework to describe their understanding of carcinogenesis. Specifically, students were asked to construct a visual representation of their carcinogenesis model using a multi-dimensional presentation tool in the cloud. The student model was developed during the semester; Students have customized their maps in response to a growing knowledge base and formative feedback from instructors and peers. The task of the synthesis map can be considered the evolution of the concept map. Conceptual map as a student learning tool was developed in the 1970s by J. D. Novak and is on the theory of cognitive learning by David Ausubel, which emphasized meaningful learning (Ausubel, 1962). The purpose of using conceptual maps as a student's task in classroom learning is for students to explicitly establish a personalized, hierarchical organization of their understanding of a particular subject or concept. As a student learning strategy, teaching tool and tool for a formative and summative assessment of student understanding, this tool improved scientific education (Novak, 1990). Successfully implemented concept map tasks inspire student metaognics by encouraging students to examine their own knowledge structures, and repeated use of concept maps can reveal how these knowledge structures change over time (Novak and Gowin, 1984). Mapping the concept as an iterative exercise challenges students to organize their knowledge, analyze the validity and effectiveness of that organization, and even produce new or modified knowledge structures. It is a tool that includes higher levels of Bloom taxonomy in the cognitive domain (Peresich, al., 1990; Anderson and Krathwohl, 2001. It has also been shown to encourage positive learning behaviors in the affective domain, such as students' ability and willingness to receive and respond to information (Krathwohl, al., 1964; Maas and Leauby, 2005. This increase in positive affective behaviors not only encourages meaningful learning, but also significantly reduces students' anxiety about learning biological sciences (Jegede et al., 1990). As internet use became more popular and affordable in the 1990s, software that makes it easier to create a concept map became more accessible. One example of such software is the free-to-download CmapTools software developed by the Institute for Human and Machine Cognition. This and other software have improved students' ability to construct concept maps. Overall, advances in technology make great progress in how educational tools are implemented, and in 2003 J. D. Novak commented that we need to expand our efforts to spread new educational ideas and tools (Novak, 2003). With this challenge in mind, we have developed a synthesis map, which we believe to be the natural evolution of the concept map. Like a concept map, a synthesis map is a visual representation of a student's structure of understanding and knowledge and is able to highlight the connection (or lack thereof) between concepts in the student knowledge base. However, two-dimensional concept maps are limited in scale according to how much information can fit on a single paper or screen. Synthesis maps circumvent this limitation by using the third dimension of depth to incorporate layers of information within concepts. However, the synthesis map is not just a set of layered conceptual maps. Ideally, a synthesis map can be used to display hierarchical knowledge structures in the same presentation as the timed process and spatially represented physical structures that are relevant to the subject matter of interest. When used appropriately, the synthesis map can simultaneously present a detailed model of students' understanding of several broad subjects, illustrate the connection between these subjects, and deeply delves into the details of each topic. In particular, we have developed a synthesis map exercise to target the higher levels of Bloom's taxonomy in the following ways: the assignment requires the student to analyze and categorize information, each student must construct and develop their own unique knowledge structure, and each student is required to evaluate and summarize research related to their subject to provide evidence support to the model they have built. In implementing this new type of learning and assessment tools, we used the currently available, free to use the Prezi presentation software. Prezi is a presentation tool in the cloud that enables seamless horizontal transitions, and combines this utility with user interface zoom (ZUI) that allows the author of the presentation to use depth and distance to display links between data, ideas, and concepts (Conboy, al., 2012). Users can import images into the Prezi interface, as well as create their own images and organizational structures and icons. Prezi can be used to create traditional concept maps without depth or to create a linear presentation similar to a PowerPoint presentation. Prezi, however, also allows the user to create more, hierarchical knowledge structures in the same presentation and provides the opportunity to explore these structures on a unique, nonlinear path (Rockinson-Szapkiw et al., 2011). We used a tool to evaluate the synthesis map in the context of a biological sciences course covering cancer biology. This class is designed to provide an introduction to the fundamental principles of cancer development that come out of a vast and growing collection of facts about this disease. The synthesis map has particular usefulness in biological scientific courses due to the high degree of association between biological concepts, a large range of physical proportions in biological organisms (from individual atoms to entire populations) and a wide range of conceptual depth associated with biological knowledge (Smith, al., 2013). In the context of the range of scale and depth inherent in biological sciences, Prezi's ZUI can demonstrate its usefulness. Students in this class constructed synthesis maps as visual representations of their carcinogenesis model. One of the challenges in understanding a complex process such as carcinogenesis is fitting different components into a coherent whole. By constructing visual representations of their model (which, by definition, changes in response to new knowledge), the students clarified and structured their growing understanding of carcinogenesis. In this study, we examined synthesis maps the students produced in this course, asking the following questions: What descriptive statistics do we observe for the maps produced in this course? Did any dimension of these descriptive statistics predict a more effective synthesis map? What organizational strategies were used by students? Were these organizational strategies equally effective? Did the elements of the synthesis map construction predict success on other, more traditional student learning measures? This study therefore falls into the category of what is the taxonomy of scholarships for teaching and learning studies, trying to describe the component features of the synthesis map learning tool (Hutchings, 2000). In this paper, we describe our observations on the organizational strategies of students used to create synthesis maps and how students' organizational constructs can reveal the nuances of their understanding (or lack of understanding) of the subject. We also achieved maps based on four criteria (organisation between categories, organisations within categories, accuracy and completeness) and presented these results. Quantitative, correlative analysis shows that elements of student organization of the synthesis map interact with other class metrics, suggesting a potential tool for detecting student understanding that is especially important for success within the course. One area where greater development is needed in educational research are recommendations for the practical application of concept mapping as an assessment method (Ruiz-Primo and Shavelson, 1996). To this end, we have included a number of best practices developed during a retrospective analysis of the synthesis map task. We hope this work will provide a clear guide for other life sciences educators to use the synthesis map technique we have developed, using current technology to improve and develop a well-established teaching tool. The study was conducted in a course in biological sciences at Vanderbilt University, a medium, highly selective, private, research-intensive university in the southeast of the United States. The course, which focused on cancer biology, is an elective course aimed at younger and senior students from a mix of science and engineering. The C.J.B. investigator was a course instructor. Students completed a synthesis map assignment as part of their usual course work. After completing the course, students received two letters: one letter asking permission to use their class data in the study, and another letter asking permission to use images from their map as examples in the results of a handwriting reporting study. Copies of letters can be found in Supplementary Materials (p. 1–2). The study was conducted under the approval of the Vanderbilt Institutional Review Board. Of the 27 students, 24 agreed to participate in the study. The synthesis map project was introduced on the first day of (see Complementary material, p. 3-8), which provided a brief description of the objective and format of the project. During the third week of classes, the project was reviewed, and one class day was spent on the first steps. In particular, the students gathered themselves into groups of three and compiled their first synthesis map on paper based on the following order: Work with two classmates to create your first synthesis map (20 minutes). First, compare your lists of things you know about developing cancer. Talk until you get on a shared list. If there is a strong discrepancy, then the lists for three people do not have to be identical. Second, think about how you would visually represent these ideas. It sketches at least one possible visual that includes all the things you know. It can include symbols, real images, tags, videos, etc. You can think in terms of scale, zoom in and out. The instructor then introduced the Prezi tool and guided the class as a whole through the initial steps of creating Prezi, with individual students creating their new Prezis on their own laptops. Students were encouraged to collaborate with two members in their individual groups when designing their synthesis maps, but had to make their own presentations on their own. In making maps, students used the course textbook as the main but not exclusive source of images they incorporated into their maps (Weinberg, 2007). Since the images were used for educational purposes, were limited to use by class members and were not freely available, this use falls within the fair use of the material (see, for example, description here: www.copyright.com/Services/copyrightoncampus/basics/fairuse_list.html). After the initial submission, each student received formative feedback from the instructor and from two peers in his group. Groups remained constant throughout the semester. Students submitted their synthesis maps three more times during the semester, revising them and expanding how their knowledge grew. Each time, they received formative feedback from instructors and two peers, and the feedback consisted of written comments identifying strengths and weaknesses in the organization, clarity, accuracy and completeness. No grades were awarded before the final submission. Mid-term submissions were important for the final grade, however, as each submission entitled the student to 20% of the final grade; that is, a student who missed a midterm submission could earn a maximum of 60/75 on the final synthesis map. Student synthesis maps were initially evaluated by a course instructor (C.J.B.), using the evaluation section of the supplementary material (p. 9); The section was developed in collaboration with students in the class and consisted of a total of 75 points. After completing the course, maps drawn up by students who agreed to be part of this study were analysed separately by both using the custom form of the section used during the course. The maps were assessed on the basis of the presented organization between the main concepts associated with tumorigenesis, the organization within these main concepts, the accuracy of the information presented and the integrity of the map. Each of these components is assigned a score of 0 to 10, and 10 is the best possible result. The overall score for each card was the combined results of these four components for a total of 40 possible points. The total number of slides students used for each map was also counted, and the maximum installation level for each map was determined. Once individual results have been awarded, a consensus score for each category of each map has been established during the analysis of each map. To investigate students' choices in constructing their synthesis maps, we analyzed the characteristics of their maps. We asked two questions about each map: What organizational strategies did the student use? and What organizational strengths and weaknesses have we observed? To solve these issues, we used a modified approach to grounded theory (Strauss and Corbin, 1990). The authors briefly reviewed all the maps together, identifying potential topics. Each author then independently reviewed the maps to answer these questions, categorized the answers, and then examined the categories to identify the topics. Next, we compared our analyses, in most cases the consistent differences to come up with a single interpretation. Quantitative data from students from the synthesis maps described above were collected, as well as data on student exam grades, final grades on paper and final grades. These quantitative components were analysed for correlations by determining Pearson's correlation at the time of the product and calculating p values associated with tests of significance for these correlations. Correlation tests that resulted in Pearson statistics |1–0.7| were considered to have a strong correlation, values of |0.69-0.4| were considered to indicate moderate correlation, values |0.39-0.1| were considered to indicate a weak correlation and values of less than |0.1 | were deemed not to indicate a correlation. Correlations analyzed by regression analysis were made by a simple liner regression model created by the usual least square method. Linear regressions are shown in the standard form for the linear equation: y = mx + b. p Values are calculated for each line regression. p Values < 0.05 indicate that the predictor variable significantly explains some part of the variation in the response variable. This section is marked with an R2 value. We examined final synthesis maps for 24 students from a class of 27; the remaining three students either did not respond to requests for permission to view tickets or deleted tickets from their accounts. All synthesis maps represented seven main components of cancer development Of course, although the depth and style of this representation varied: the progressive nature of carcinogenesis, the role of accumulation mutations and genetic reshuffles, proto-oncogens, tumor suppressor genes, immortality, interactions with non-cancerous cells and metastases. All the maps we reviewed were multilayered, and all students used the Presi zoom feature to incorporate information into larger concepts; the degree of layering varied from two layers to five layers. In addition, students uniformly created paths through their maps, allowing viewers to click through the tracking steps through the map. The lengths of these paths varied, ranging from 56 to 141 frames, and students typically used arrows and guiding text to help viewers understand the organization. In some cases, students created paths that covered all map features, while other students included additional features that could be explored regardless of the planned path. Students used three main organizational strategies when creating their maps: conceptual, spatial, and narrative: Students using conceptual organization identified certain cancer development features, such as the above components or cancer features identified by Robert Weinberg (Hanahan and Weinberg, 2000), and each of them they used as a nod in their maps, describing each feature relatively independently of the others. Essentially, the maps using this organizational strategy resembled a collection of concept maps or a visual representation of outlines. Figure 1 shows a screenshot of a synthesis map that relied primarily on conceptual organization. Students using spatial organization created structures that explicitly meant to represent physical components associated with a particular concept. For example, students using this organizational strategy often created images of normal and cancerous cells and built-in features that differed between them, such as specific mutation repair systems or cell surface receptors. Figure 2 shows screenshots of a synthesis map that relied primarily on spatial organization. Students using a narrative organization used the Prezi tool to tell the story of a mapping phenomenon. In general, students would illustrate tumorogenesis events in the order they usually occur and integrate major concepts along the timeline. Figure 3 shows a screenshot of a synthesis map that relied heavily on narrative organization. Although students typically adopted one of these schemes as their primary organisational strategy, most used elements of other organisational schemes as needed (Figure 4). For example, the synthesis map shown in Figure 3 primarily used a narrative organizational scheme, but included some conceptual organization (frames 24-35 within that map). All three organizational strategies enabled effective embedding. We asked if organizational strategy (conceptual, spatial or narrative) or strategy was more effective than other combinations. Venn diagrams at number 4 show that most students used some form of conceptual organization in their synthesis maps. Synthesis maps that used only spatial or narrative arrangement or combined were less popular options, but a breakdown of the results of the synthesis map and results for synthesis map indicates that all organizational schemes favored the successful creation of a synthesis map. All three primary strategies and their combinations seem to have enabled the effective organisation of maps, although it seemed that purely conceptual organisation - similar to the visual outline - was slightly less effective in conveying the relationship between concepts. We found that the maps offered insight into how students conceptualized the relationships between large components of cancer development. For example, the map shown at number 1 uses different circles on the map to describe components of cancer development. The author does not make the relationships between these components explicit; implicit connections are obvious to a knowledgeable, attenual viewer who records an example of proteins that appear in two or more circles, but the author of that connection does not seem explicit to the viewer. The author, however, chose many images from sources other than textbooks (~40% of the total), including many that were not used in class materials. Furthermore, these images usually convey a rich meaning within the map. Thus, this student's decision to find images beyond those used in the class to illustrate the conceptualization of cancer suggests a well-developed structure of knowledge, despite the lack of explicit connections between concepts. The map shown in Figure 2 shows the highly integrated structure of knowledge around cancer cells – stromal (heterotypic) interactions, angiogenesis and metastasis, with spatial map organization that facilitates concise and high visual integration of topics. The map shown in Figure 3 shows another mechanism for linking cancer components, using questions or brief statements, often narrated through the Unveiling function in Prezi, to draw explicit relationships between topics (see boxes 35, 66, 82-83, and 92-94 for example). Missing or unclear links can also be informative. For example, the map shown in Figures 3 includes p53 and Rb as examples of tumor suppressor proteins, but does not link the inactivation of these proteins to cell perpetuation through escape from senescence. This absence can reveal a mental silo of information rather than a fully integrated understanding of these related topics. Other examples have found greater difficulties in organizing information. One map we were investigating showed several completely unrelated nods inside the map. Within several of these nods, there were large blocks of very detailed text and multiple images that support text. However, any nod would be incomplete and unrelated to other nods. Overall the map was disorganized and scattered. Taken together, these observations suggested that the student was having difficulty incorporating detailed information into a large, integrated framework. In other words, the student seemed to get lost in the details of a particular nod, then jumped out, started another cumin and repeated the process. The maps also provided insight into the inclusion of students' evidence in their personally synthesized knowledge structures. For example, the map shown in Figure 3 repeatedly includes evidence in the cancer progression section (see, e.g., boxes 13, 14, 16-22). However, none of the maps examined included significant evidence in the proto-oncogen and tumor suppressor genes sections, suggesting a possible deficit in instructional materials. Effective features of the synthesis map. Each synthesis map is scored for organization (between concepts and within concepts), accuracy and completeness using the section described in the supplementary material. All in all, student tickets were very accurate, complete and well organized (Table 1). The average grade on the project was 84%, and one student earned the perfect grade. The distribution of pupils' scores shown in the histogram (Figure 5) is visually approximate to normal distribution focused on B+ or A−grade. More students scored perfect on individual metrics. Of the quantitatively estimated metrics, the accuracy of the map had the highest average score and the smallest deviation. Statistics for grade values given to student synthesis maps covering organization, completeness, and accuracy, as well as for synthesis map total score and descriptive metrics: maximum levels of embedding and number of slidesMeanSDRangeOrganization between major concepts8.16 out of 100.304–10Organization within major concepts8 out of 100.294–10Completeness8.33 out of 100.236–10Accuracy9.21 out of 100.197–10Total score33.7 out of 403.8621–40Maximum levels of embedding3.330.162–5Number of slides in presentation984.856–141Although some students only minimally utilized the embedding feature of the Prezi software, every student created embedded information in his/her map to some extent using the ZUI, with most students implementing more than two levels of depth to indicate that a certain piece of information or a concept belonged in a hierarchical subset of the one above it. The largest range in any metric was in the number of slides used to create each student's map. The set of results listed in each metric described above has been compared with each other to determine whether there are correlations between the different metrics that make up the synthesis map task. Pearson correlation statistics at the time of the product were calculated to determine the correlation between the different datasets (Table 2), and correlations were verified for significance by calculating the p value for each correlation (Table 3). For Pearson statistics, p value < 0.05 means we can refuse correlation is due to accidental sampling, indicating that the correlation is significant. Pearson Product-At-Product Correlation Statistics (r) for Different Components of The Synthesis Map TaskOrganization Between ConceptsOrganizations Within ConceptsCompletenessAccuracyLevels InstallationNumber of SlidesIt ScoretalOrganization Between Concepts1Organizations Within Concepts0.581Completeness0.200.431Accuracyaccuracy0.54 0.690.611Levels installation0.260.590.370.511 Slide count0.060.080.540.030.301Total result0.790.880.610.800.550.211p Value (p) for correlation statistics for different components of the synthesis map taskOrganization between conceptsOrganization within conceptsCompletenessAccuracyLevels installationNumber of slidesTotal scoreOrganization between conceptsOrganization within concepts0.071Competitet0.890.21Accuracy0.0830.010.26Levels installation0.150.0050.160.01 Slide count0.670.800.0020.930.17Total score0.0081.5 × 10−60.013 × 10−64.3 × 10−40.17 Correlations between the different components of the synthesis map reveal important information about the learning tool, not only with components that are significantly correlated, but also with components that are not significantly related. For example, two categories of organization, as well as completeness and accuracy, are expected to correlate moderately or strongly with the overall score, as the sum of the results from these components makes up the overall score. However, the maximum installation levels used in the map are significantly, moderately correlated with the overall score (p = 4.3 × 10−4), indicating that while this component did not contribute numerically to the overall score, it contributed in other, less obvious ways. Antithetically, the total number of slides used in each presentation is not significantly related to the overall rating. In fact, the only significant correlation for the number of slides used is the moderate correlation with completeness, indicating that while the number of slides does not have a strong effect on organization or accuracy, it has an effect on the completeness or perceived completeness of the map. Going further, this implies that there is a minimum number of slides that must be used to include all the necessary information for this particular task. The synthesis map task is designed to provide insight into students' knowledge structures, so that the organization of maps is of particular interest. The ratings for the organization between the main concepts are not significantly correlated with the assessments for the organization within the individual topics covered by the maps, but the p value (p = 0.071) is close enough to significant to indicate that a larger sample size may be required to demonstrate true significance. However, the organisational strategies and objectives for these two categories are not necessarily similar. This is evidenced by the fact that one of the measurable measurable metrics of the organization, the it is used on the map, significantly correlates with student results for organization within concepts, but does not correlate with the organization between concepts. By its very nature, this prezi software capability lends itself to increasing the amount of fine detail and displaying the underlying organizational structure within the structure in which data or concepts are embedded. It is also interesting to note that the level of installation has a significant moderate correlation with the accuracy of the map, which indicates that one component of accuracy can be the way a fine detail of the knowledge structure is arranged. Certainly, clearly, a deeply organized map represents a greater occurrence of accuracy than a cluttered or shallow map. Correlation with other class metrics. To determine whether any element of the synthesis map can provide special value to promote student success, we analyzed map results and map results components against other class success metrics: combined exam results, final paper scores, and class grade without a synthesis map included. Table 4 shows data extracted from correlation tests between synthesis map components and other class metrics. In particular, we observed a significant, moderate correlation between students' ability to illustrate the organisation between concepts and their performance in course exams and in the final assessment of the course (Table 4, rows 1 and 4). Correlation statistics and p values for synthesis map components and other classroom metricsUrelated dataCorrelation statistics (r)p ValueClass score without a map compared to. organization between terms0.430.035Classes score without a map versus accuracy on the map0.440.032Classical result without a map versus organization within the concepts0.110.61Total exam result vs. organization between concepts0.580.003Total exam result versus. Organization within the concepts0.230.23The current result of the exam versus the results of the synthesis map0.440.032Final level of paper versus the results of the synthesis map0.050.83Final paper class vs. organization between concepts0.060.78Linear regression was carried out after a correlative analysis of student data. to determine whether certain components of the synthesis map can act as linear predictor variables for other ongoing success measurements. The organization between the main concepts on the map is of particular interest, as it has a significant correlation with the grade score and overall exam score. Figure 6 shows linear regressions with organization between the main concepts on the synthesis map as predictor variables for the grade score and overall exam score. Variations in results for organization between concepts on the synthesis map can account for ~33% variation in combined exam score and 25% variation in class. This illustrates the power for students to examine and explicitly form their knowledge structures. The result for the organization between concepts makes up a small part of the final score for the synthesis map, which in itself is only 14% Grades. Nevertheless, this metric may explain a large part of the variations in the class. These results suggest that formative feedback on this synthesis map element may have potential greater effects for student performance in the course. The way students organize their maps with regard to the relationships between the main concepts of tumorogenesis represents their broad understanding of these concepts and their large mental models that connect these subjects. The way students organize the data and evidence presented within each major subject or category provides insight into the finer structure of their understanding, as well as how they evaluate and incorporate actual data into their personally synthesized knowledge structure. It is a combination of these two organizational metrics that reveals the hierarchical nature of student understanding and shows how they move from gross to fine structuring of knowledge in relation to the chosen theme. As with conceptual maps, the organizational structure of the synthesis map is most important for detecting student misconceptions and teaching problems. Maps explicitly visualize students' strengths and weakness on different organizational ladders. For example, some maps had a strong large organization between the main concepts, but they had little data, detail or evidence. This indicated that these students may have had a strong, gestal view of tumorigenesis, but either did not have internalized information related to the fine details of these terms or did not have a deep cognitive organizational structure for these concepts. Other maps had a large amount of small detail within the individual concept, but little connectivity or an incomplete final structure. Some maps existed between these extremes, indicating where the indirect understanding of students or mental organization might lie. Misunderstanding of individual students can be diagnosed by using the synthesis map as a formative assessment tool and by looking for errors in the structure of knowledge, content errors or content omission (McClure, al., 1999). Instructional issues are likely to lead to multiple cards displaying the same or similar error.s). Once detected, class errors or omissions can be corrected in class and/or the curriculum can be adjusted to future classes. By examining and testing students' knowledge structures with synthesis mapping, it is possible to engage students in a different way compared to purely objective assessment methods such as multiple choice and short answer. Concept map results are known not to correlate well with multiple choice results, suggesting that mapping exercises evaluate different skills, such as higher-level skills in the cognitive domain of Bloom's taxonomy (Morse and Jutras, 2008). This different method of engagement from the material of the course can have a positive impact on students for whom lectures and text are not the optimal learning path. Relational knowledge with the synthesis map is something that students must construct for themselves, and the act of creating a relationship between existing knowledge and new knowledge creates meaningful learning (Novak, 2003). Our observation that students' ability to illustrate organisation between the main concepts can predict their success in other measures (i.e. test scores and final grade) corresponds to Bransford and the identification of fellow conceptual frameworks as key to learning (NRC, 2000). It may also suggest that helping students develop a broad, well-connected conceptual framework early in the course can improve their overall learning. By explicitly helping students develop such a broad framework before moving on to more nuanced data-driven details, instructors may be able to accelerate their students' progress toward knowledge structures to a similar expert. This observation can be especially important in cell and molecular biology courses such as cancer biology used here as an example, whereby a highly inductive approach to research can lead to courses focusing on concepts that emerge from examples. Teaching requires simultaneous allocation of resources for students and instructors in search of multiple goals. Every new teaching technique must be required: Will it be worth the effort? We've included some suggested best practices for instructors who are conducting a synthesis map that will increase the effectiveness of this teaching tool and reduce the wasted effort:Introduce a task early in the semester. One concern with mapping the concept as a teaching tool is that it takes a significant amount of time to teach and implement concept mapping in the classroom, especially with students without practical exposure to technique (Maas and Leauby, 2005). Synthesis mapping is inherently more complex than mapping the concept, so it requires even greater time commitment and more practice/procedural teaching. On the sleuth of an explicitly provided audience. Synthesis maps could be used for different purposes: share only with the instructor to discover knowledge structures, share with peers within the class to help learn, or teach specific topics related to larger class topics, share on the web for general education purposes, use in teaching projects with younger students. Each of these opportunities represents a different audience that can be expected to bring different initial knowledge. Being explicit with students about the intended audience will help them consider the background they need to provide and the level of detail that will be appropriate. Describe potential organizational strategies. To give students the freedom to develop their own visual models, we deliberately gave very rare instructions on what synthesis maps should look like. While this approach was effective for most students in the course, some students were more comfortable than others, some of whom were vaccinated between However, describing potential organizational strategies that others have used may allow some students to deliberately choose the approach that best suits their mental model. Encourage students to make a rare map early in the process and have them revise and iterate. The most successful students chose the organizational strategy and used it consistently throughout the map. Some students started their map from scratch late in the semester, neglecting their earlier work. These examples generally had a more sophisticated and coherent organization, but they often lacked complete. Suppose it was caused by fatigue associated with trying to finish the whole task from scratch late in the semester. That students work in groups to provide feedback and affective support. It turned out that students working on concept maps in teams are more successful on the task (Morse and Jutras, 2008). With the task of synthesis map, we have also seen cases of convergent design in many groups. In these groups, students can learn from each other and receive regular peer feedback. Let's say this feedback provides positive affective support to students and increases problem solving performance and success on the task. One negative effect of small groups that must be acknowledged is the possibility that convergent design could potentially mask students' personal understanding or force them to adopt another student's organization. Allow more examples for student feedback, which may come from other members of their small groups, and from more formalized instructor feedback during the semester. The basic process of mapping the concept is not necessarily iterative; formative assessment using concept maps can take only a few minutes in class. Due to the increased complexity inherent in the creation of the synthesis map, the process should go through several iterations of map construction, followed by feedback and modification (Allen and Tanner, 2003). By providing regular, non-degradable feedback, instructors can use the synthesis map as another method of teaching throughout the course and as a means to help students address their misconceptions and evaluate students' learning at the end of the course. Furthermore, by regularly examining students' synthesis maps, the instructor can achieve increased awareness of potential teaching errors and can correct these errors if necessary. Instruct students to use the embed feature and to show examples of effective embedding. Our results show that effective use of ZUI to incorporate information improves the organization of student synthesis maps. This is especially important, because the organization of hierarchical maps of knowledge is more important for the success of students on the task than the actual information that is presented (Morse and Jutras, 2008). However, the installation function may not be intuitive for all students. This is why it is useful if provide examples of what they see as effective embedding when introducing students to this feature. It is important to note that this is not the same as the instructor creating the master card or the answer key to which student synthesis maps can be evaluated. While using the master map can be useful for using conceptual maps as a summative assessment tool, the added level of organizational freedom offered by prezi software allows for extreme variations in map design. Although small, student-produced concept maps can converge on what can be considered a proper organization, this convergence has not been seen with synthesis maps (McClure, al., 1999). Encourage students to create their own representative structures and diagrams on the map instead of relying on too-detailed structures and published images. Students who created their own visual structures as opposed to using images from texts or articles in magazines were very successful. For example, some students used available software to create their own views of path diagrams, including proteins in pathways, that were seamlessly integrated into other structures in the presentation. This allowed students to fully realize their personal mental organization of these concepts. Identify the value of a map by awarding a significant number of points. Synthesis maps that represent a large part of the course's content and have been iteratively revised require significant time investment by instructors and students. For a task to be worth the time invested, it is important to give a significant number of points for its completion. As with any task, the actual dotted value and time allocation must depend on the place that the synthesis map occupies in the overall course plan. For example, if an exam is worth 25% of the points within a course and should require studying seven off-limits hours a week for 4 wk, then it would be reasonable to make a similar calculation for a synthesis map covering the same scope. It is worth noting that evaluating synthesis maps can be similar to evaluating student writing, with the same potential for spending time. Therefore, it is important to set guidelines to help you keep the evaluation efficiency in line with your expectations for the project. Educational blogs provide more suggestions for improving efficiency, and one example are the challenges for applying technological advances to instruction and assessment given to their students. Synthesis mapping uses a new, multidimensional presentation tool to allow students to create a detailed map of their hierarchical knowledge structures. By using ZUI to incorporate knowledge and concepts within a map, students can create maps of greater complexity than what is allowed to use traditional tools and strategies to map concepts. This increase in scope and complexity students engage higher-level cognitive skills. Synthesis mapping is an explicitly constructivist tool, as it directly models the constructivist process. Like the conceptual map, it can be used to promote and even force students to take a meta-ognitive approach to understanding their own knowledge structures. It also challenges students in ways that other methods of evaluating the course do not. Knowledge mapping is a very effective for formative assessment tool. When used successfully, synthesis mapping can be used as a formative assessment to detect the benefits, misconceptions and organizational schemes of students, and as a summative assessment to test the understanding of of course student material and their ability to use and evaluate this material. The authors thank the students who agreed to participate in this study. We especially thank John Cao, Saad Rehman and Emily Summerbell for allowing us to publish images from their synthesis maps and provide links to their maps in this article. Allen D, Tanner K. Approaches teaching cell biology: mapping travel concept maps as a signpost for the development of knowledge structures. Cell Biol Educ. 2003;2:133–136. [PMC free article] [PubMed] [Google Scholar] Anderson LW, Krathwohl DR. Taxonomy for Learning, Teaching and Evaluation: Revision of Bloom's Taxonomy of Educational Goals. New York: Longman; [Google Scholar]Ausubel DP. The theory of subsumption of meaningful verbal learning and retention. J Gen Psalm. 1962;66:213–224. [PubMed] [Google Scholar] Conboy C, Fletcher S, Russell K, Wilson M. Evaluation of the potential use and impact of Prezi, software for editorial zoom, as a tool to facilitate learning in higher education. Inn's Pract. 2012;7:31–45. [Google Scholar] Hanahan D, Weinberg RA. Cancer features. Cell. 2000;100:57–70. [PubMed] [Google Scholar] Hutchings P. Introduction. Opening statements: Approaching the scholarship of teaching and learning. San Francisco: Jossey-Bass; 2000 p. 1–10. [Google Scholar] Jegede DR, Alaiyemola FF, Okebulola PA. The effect of concept mapping on student anxiety and achievements in biology. J Res Sci teaching. 1990;27:951–960. [Google Scholar] Khodor J, Halme DG, Walker GC. The concept framework of hierarchical biology: a tool for the design of the course. Biol Educ Station. 2004;3:111-121. [PMC free article] [PubMed] [Google Scholar] Krathwohl DR, Bloom BS, Masia BB. Taxonomy of educational goals, book 2: Affective domain. New York: Longman; 1964 [Google Scholar]Maas JD, Leauby BA. Concept mapping – exploring its value as a meaningful learning tool in accounting education. Global Perspect Account Educ. 2005;2:75-98. [Google Scholar] McClure JR, Sonak B, Suen HK. Assessing the concept of classroom learning: reliability, validity and logistical convenience. J Res Sci teaching. 1999;16:475–492. [Google Scholar] Morse D, Jutras F. Conducting conceptual learning in a large undergraduate classroom. CBE Life by Sci Educ. 2008;7:243–253. [PMC free article] [Google (Google) (Google) Research Council. How people learn: brain, mind, experience and school, extended ed. Washington, D.C.: National Academies Press; 2000 [Google Scholar]Novak JD. Concept mapping: a useful tool for scientific education. J Res Sci teaching. 1990;10:923–949. [Google Scholar] Novak JD. The promise of new ideas and new technology to improve teaching and learning. Cell Biol Educ. 2003;2:122–132. [PMC free article] [PubMed] [Google Scholar] Novak JD, Gowin DB. I'm learning how to learn. Cambridge, U.K.: Cambridge University Press; 1984 [Google Scholar]Peresich ML, Meadows JD, Sinatra R. Content area cognitive mapping for reading and expertise. J. Reading. 1990;33:424–432. [Google Scholar] Rockinson-Szapkiw AJ, Tucker JM, Knight A. Prezi: Trading linear presentations for conceptual learning experiences in counselor education. Blacksburg, VA: Higher Education Pedagogy Council; 2011 www.works.bepress.com/amanda_rockinson_szapkiw/18 (accessed 1 June 2014) [Google Scholar] Ruiz-Primo MA, Shavelson RJ. Problems and problems in the use of conceptual maps in the assessment of science. J Res Sci teaching. 1996;33:569–600. [Google Scholar] Smith JJ, Cheruvelil KS, Auvenshine S. Assessment of student learning associated with thinking about trees in the undergraduate course of introductory biology of the organism. CBE Life by Sci Educ. 2013;12:542–552. [PMC free article] [PubMed] [Google Scholar] Strauss A, Corbin J. Basics of Qualitative Research: Established Theoretical Procedures and Techniques. Newbury Park, CA: Sage; 1990 [Google Scholar]Weinberg RA. Cancer biology. New York: Garland Science; 2007 [Google Scholar] Scientist]