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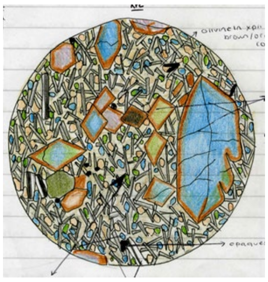

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CASE STUDY

Does Sketching promote student learning? A review from Undergraduate Geology

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Abstract

Sketching is an important way in science and other disciplines for illustrating complex concepts with more digestible formats and has therefore long been engrained in the field of Geology either for research or teaching purposes. The following report outlines an assessment of a compulsory second year undergraduate geology module where illustrations are implemented and form a key part of the student's learning process. The intended learning outcomes are assessed through the submission of a practical folder and an exam including a practical component. The module receives critical but highly positive reviews from the student cohort who achieve overall good marks. However, a key difference in student performance between the practical components of the exam compared to that of the coursework is apparent. Practical components are problem-based and intended to offer the students an opportunity to engage with the complexity of a given task and sketching is intended to increase the student-learning process through exploration. The benefits of sketching are unequivocally clear but it remains open whether students use illustrations to enhance the learning process to their full potential. Introduction of a learning-cycle approach appeared to have improved student performance and is recommended to promote student learning.

Keywords: conceptual sketches; geology; deep-levels of learning; teaching practice

Aims and purpose of this study

The field of Geology relies heavily on illustrations and visualizations to help convey often multifaceted and complex information in one or several simple images. The aims of these illustrations are to synthesise large amounts of data or complex concepts into more digestible and comprehensible forms. The significance of illustrations has therefore long been engrained in the field of Geology both for research or teaching purposes (e.g. Rudwick, 1976). Sketches are an important way of recording our observations and thoughts as scientists and convey ideas to our peers, students and the general public. It seems therefore reasonable to assume that geologists are natural sketchers through the extensive practice we have in our field notebooks, publications, formal and informal presentations and drawings to illustrate concepts during teaching sessions. Everyone can make a drawing but not everyone is an artist, yet drawing, even in a primitive way, often triggers insights and discoveries that are more complex to follow or understand through the use of words alone. As sketching is an important way of making ideas and thoughts visible and of enhancing the learning process for students of geology, or earth sciences in general, students are exposed and encouraged to make sketches from a very early stage (Figure 1).

The questions to be addressed and problems reflected on in this case study are:

- Does sketching promote deeper levels of learning of undergraduate students?
- Could student performance be improved by teaching concept sketching?

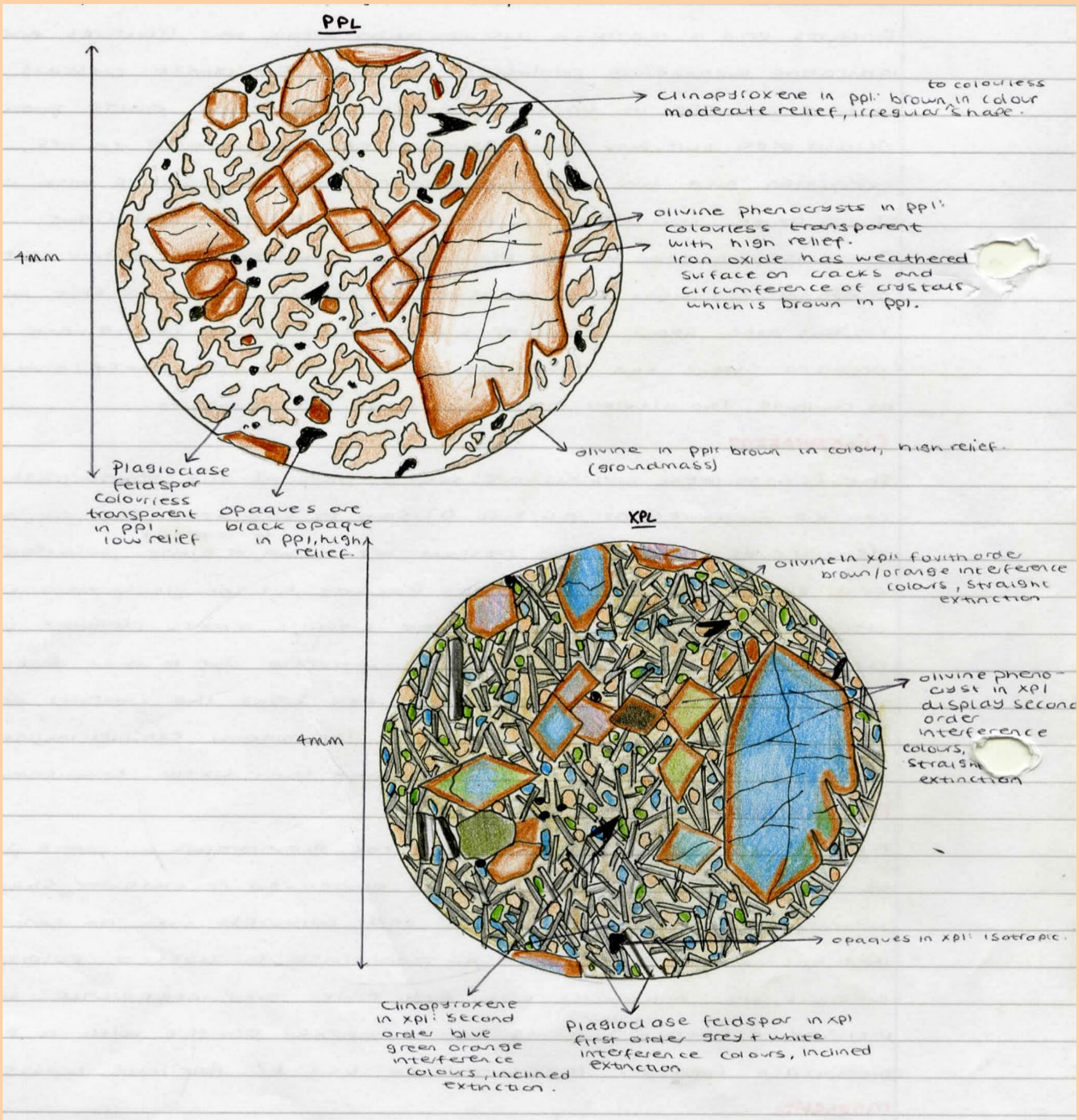

Figure 1: A) An exceptional example of student concept sketch of a rock thin section with annotations illustrating the different minerals and their growth relationship (i.e. the rock texture). This example is taken from a 2nd year undergraduate student's submitted course work (practical folder).

Figure 1: B) example of an early concept sketch from a 1st year undergraduate student for comparision. C) conceptual sketch of student example 'A' now including analyses and interpretation.

Reasons for choosing this topic

Sketching is an important way in science and other disciplines for people illustrating their thoughts (Temple, 1994). It is generally accepted that through practice every person will improve their understanding and ultimately their performance. However, most Geologists are no artists and additional time to practise this skill is therefore often allocated. Sometimes in very long and, reflecting on my own experience as a student, tedious sessions. In the following report I want to outline objectives of a second year Geology module where illustrations are implemented and form a key part of the student's learning process. The module is a compulsory component within the Geology degree program, which I have taught for the last three years. The intended learning outcomes (ILO's) of the module are assessed through the submission of a practical folder (coursework component) and an exam including a practical component. Students are required to draw sketches and illustrate observations and interpretations in both components. The exam and practical folder contribute with 80% and 20%, respectively, to the final module mark. The module, although generally considered by the student as challenging, receives always very positive feedback and overall results are good. For instance, the final year mark for this module averaged 59.4% and 57.2% at the first and second year of teaching, respectively. However, close inspection of the practical components which rely on sketching reveal a discrepancy between the coursework and exam marks of individual students. Accordingly, the present report aims to review whether the application of sketching promotes deeper levels of learning, increasing retention of the studied material and ultimately improving the performance of undergraduate Geology students.

A Review of the Relevance of Sketching

The processing of information or the management of knowledge can be considered to have grown out of the understanding that the mere reliance on our capability to simply process information is insufficient (Pfister, 2013). Sketching in general can be considered a tool of thought that enables the mind to capture things which are in flux and iteratively refine them (e.g. Larkin and Simon, 1987; Buxton, 2005) or in other words to simply help digest complex thought processes. There are numerous examples where sketching has helped scientists to develop their ideas and understanding, most famously Charles Darwin, who used sketches to develop his theory of evolution, or Sigmund Freud, who used sketches to refine his theories on psychoanalysis (Pfister, 2013). Sketching is not only fundamental to Geology but also many disciplines such as industrial design, graphic design and architecture (Tohidi *et al.*, 2006). Sketches also find increased use in daily management applications as they can help to stimulate active engagement and increase sharing of knowledge (Pfister and Eppler, 2012). Furthermore, creating high-quality scientific illustrations requires a sound understanding of the topic and a major part of learning to identify geological processes is knowing the key features to focus on. The ability to see without bias and focus on details and pattern requires training and not necessarily talent.

What are concept or conceptual sketches?

As outlined above, illustrations are commonly used to simplify ideas. A concept sketch is a simplified sketch illustrating the main aspects of a concept, system, or process annotated with concise but complete labels (as shown in the student examples in Figure 1). These sketches aim to identify key features, identify occurring processes, and depict the relationships between these features and processes. A concept sketch is therefore more than a labeled diagram (Johnson and Reynolds, 2005). Johnson and Reynolds (2005) emphasis that an excellent way to use concept sketches in teaching sessions is to employ a learning-cycle approach (e.g. Lawson et al., 1989). Although, several learning-cycles exist their common elements include an engagement of students to develop sketches through exploration (exploration-cycle), introduce formal nomenclature (concept-introduction cycle) and a final cycle where students apply these skills to a new scenario (concept-application phase; see Lawson et al., 1989 for details).

Project outline – the 2nd year Geology module

Details of module syllabus and intended learning outcomes (ILOs)

The undergraduate module reflected on in this case study builds on several first-year modules, and focuses on the formation of igneous (volcanic and magmatic) and metamorphic rocks. The module is designed to provide students with a broad understanding of the processes and environments in which magmatic and metamorphic rocks form. What conditions are required to form magma and why do we find some erupting onto the Earth's surface whereas other magmas remain in the crust? Students will learn the processes by which mantle and crustal rocks melt to form magmas and the chemical and physical processes involved in cooling of magmas which result in the wide range of igneous rocks exposed at the Earth's surface. Students are guided to make observations and interpret those observations within a scientific framework through lectures and practical classes. Lectures and associated practical work follow a multidisciplinary approach using a variety of data sets including a petrological microscope to investigate macroscopic and microscopic evidence to illuminate the processes involved. This is supported by online resources, including a compilation on the theoretical background to the topic and original published literature for in-depth studies (available through the learning environment Blackboard) before each session.

'The purpose of in-class sketching'

Each pre-practical lecture is set up to introduce the topic covered in the following practical. The accompanying practical is structured to guide the students through the process of making observations and subsequently to interpret those observations within a scientific framework in line with the intended learning outcomes. Lectures and associated practical work follow a multidisciplinary approach using a variety of data sets including a petrological microscope in order to identify the rock-type but most importantly to develop a process or processes of formation. These processes can be complex and multi-faceted. The purpose of illustrating the rock samples is therefore to synthesis large amounts of data and complex concepts into more digestible and comprehensible forms. However, details of very fine-grained rocks with grain-sizes <1mm can only be identified through the microscopic investigation of a rock thin section. This method allows up to 40 times magnification. Students are instructed to make representative drawings of the provided rock thin sections (Figure 1). The purpose of this exercise is to provide details on individual rock components (minerals) and the spatial relationships between these (referred to as texture) in order to enhance the quality of the student's rock description. Students are also encouraged to take photographs of the magnified rock sections but are advised that these are not an adequate substitute for a diagram since it is often difficult to observe textural relationships in photographs. The students are advised to look first (observe), inspect the sample and explore the whole section as this will make it easier to incorporate the observations into a sketch or diagram. Furthermore, emphasis is given to consider accuracy, attention to detail, representation (e.g. one detailed over numerous sketches), and the use of colouring pencils is encouraged.

The purpose of the practical classes in which rock thin sections are examined were to identify at least two unknown igneous rocks based on:

a) Mineral identification and abundances
b) Textural relationship of minerals (e.g. establish a crystallisation sequence)
c) Address any related question.

These related questions are aimed to provoke a critical review of observations made about key features of each section. This was intentional to develop a more in-depth knowledge of the processes involved and enable the students to challenge the answer (Schwartz and Fischer, 2003).

Findings and implications - the ‘Problem’

The module receives critical but highly positive reviews from the participating student cohort and good overall marks for the last two years (averages of 59.4% and 57.2%). I was therefore satisfied that the students achieved the intended learning outcomes. The students are required to provide sketches in both the assessed exam and the coursework. However, on closer inspection of the exam and coursework results, it is apparent that most students achieved lower marks in the practical component of the exam compared to that of the coursework in each of the last two years of teaching (see Figure 2). This is highlighted by the student’s exam mark averages of 61% and 55% being lower in each year compared to the marks assigned to the student’s coursework which are on average 71% and 61% for the respective year. This difference becomes more evident in a graphical illustration of the relative difference between the coursework and exam mark performances of individual students.
A coursework to exam mark ratio (CER) was calculated to illustrate (Figure 2) whether a student achieved a higher (CER>1), the same (CER=1) or lower (CER<1) mark in the assessed coursework compared to that of the practical component in the exam.

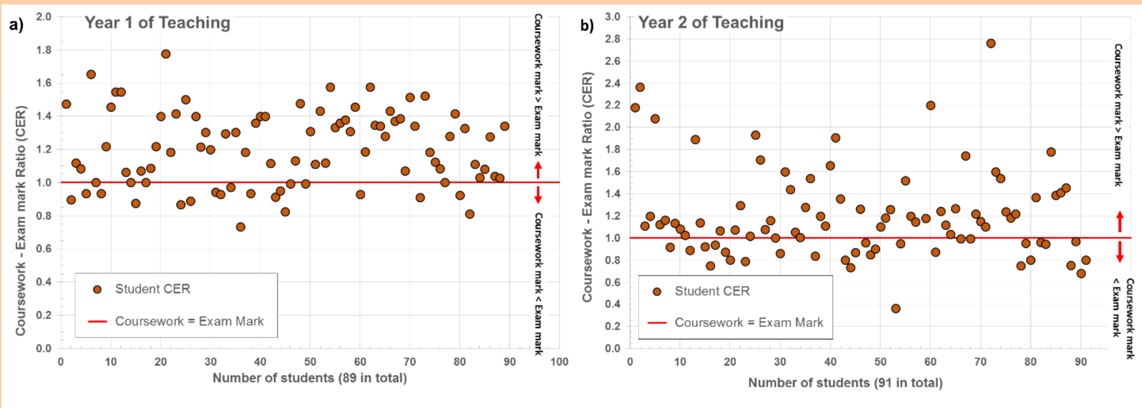

Figure 2. Graphical illustration of relative difference between coursework and exam mark
a) Year 1 results (marks in %) are shown for the coursework assignment (light orange filled circles) and for the practical component of the exam (light blue circles) for each student (89 in total). The exam practical component mark was recalculated to 100%. Note the difference in received marks between both components for most students.
The average marks for the exam (61%) and practical (71%) are indicated as solid lines, respectively.
b) Year 2 results show are shown for the coursework assignment and for the practical component of the module exam for each student (91 in total). Average marks are lower with 61% and 55%. Symbols as in a).

It is apparent from the illustration in Figure 2 that most student’s CER is above one and therefore they achieved a lower mark in the exam compared to that assigned to their coursework. These results reveal that 24 out of 89 (27%) students achieved a coursework mark equal or lower (CER<1) than the exam mark in year one, whereas the same applies for 31 out of 91 (34%) year-two students. However, 73% and 66% of all students performed less well in the exam indicated by their CER>1. This excludes students who achieved marks below 35% in either one or both components and therefore failed the module. Nevertheless, an increase in performance of 7% between year one and two can be recorded.

Discussion - The impact of this study on my teaching practice

Reflection on my undergraduate teaching

The teaching and learning approach relied on in this module resembles concepts which depend on two fundamental components with a focus on formation of conventional knowledge and procedural knowledge as discussed by Tennyson and Cocchiarella (1986). The practical components of my Geology module are problem-based and intended to offer students an opportunity to engage with the complexity of a given task and learn to manage the associated ambiguities (Savin-Baden, 2000). Sketching is intended to increase the student-learning process through exploration, concept-introduction and application of the new skills following the three main learning-cycle components outlined by Lawson et al. (1989). The students are encouraged to use concept sketches to illustrate their observations and thoughts, and through this demonstrate that they developed a better understanding of the studied subject.
However, the disconnection between coursework and exam marks achieved by the student cohort at the end of year one indicates that this goal was only partially achieved. Several student drawings are clearly exceptional but representational sketches (Fig. 1a) rather than concept sketches (Fig. 1c) which aim to identify key features and processes. This demonstrates that the students were unable to implement fully all learning-cycles and apply these to a new scenario (concept-application phase).

Education research indicates that including sketching as learning tool promotes better student learning and comprehension of the studied system or topic

As a consequence, practical-related questions aimed at provoking critical review of observations were reassessed and changed where this objective was not clear enough. It was also considered necessary to introduce the idea and purpose of concept-sketching as a new learning tool to the students. At the beginning of the module students are now asked to draw a representation of the rock thin section, which we discuss. Most students struggle with this initial task mainly as they are unsure on what to focus on and what details to include. I then ask the students to draw an image of a cat in 20 seconds, which they have to give to their neighbour. A selection of students have to describe these sketches, including the instructors, and all are projected on the wall. The students see a variety of cats which are sitting or lying, are big or small but all have key features including pointy ears, whiskers, a bushy tail, four legs and fur. We discuss this in the context of mineralogy where differing outlines and sizes of the same mineral (or cats) are referred to as the mineral habit and the alignment of minerals ('sitting or lying cats') as the texture. The students are then asked to readdress the rock thin-section to draw. These changes were implemented the following year and an increase in performance by 7% suggest that these amendments have had a positive impact.

Educational research indicates that including sketching as learning tool promotes better student learning and comprehension of the studied system or topic therefore making better use of the acquired knowledge (e.g. Novak and Gowin, 1984; Johnson and Reynolds, 2005). However, the critical review on the implementation of sketching in my second year undergraduate module demonstrates that a revision of this application was required in my teaching.

Assessing student performance - validity and reliability of the collected data

Measuring student performance is important, yet sometimes difficult to define. In this case study a key difference in student performance is highlighted by comparing data collected through standard assessment tests after two years of teaching. Therefore the effectiveness of the applied teaching methods and changes applied after the first year teaching are measured through comparing student's exam performances. The assessed practical components of the coursework and exam are instructor-generated and consequently the examined material differs between the two years. This is more so for the exam component which changes each year whereas the coursework task remains the same. This approach may be considered as ill-suited in making a quantitative comparison between student performance in different years (e.g. Bates & Galloway, 2010). Therefore, comparing data collected through standard assessment may be considered insufficiently diagnostic to imply the suggested discrepancy. The coursework and exam ratio mark provides an overall difference between both components but does not take into account external factors. Some students are more stressed during exam conditions and consequently perform less well. Even though these data are not directly comparable between the years, they still indicate a difference in performance between both components within each year. The discrepancy in marks is evident and therefore warrants a thorough reflection of this teaching and assessment component not only in Earth Sciences. The student cohorts are sufficiently high in each year (89 and 91) to provide credibility through statistical means. In order to provide a more robust quantitative evaluation and comparison between the two years, student performance should be evaluated through diagnostic testing. A diagnostic test is quite distinct from the standard assessment tests which forms part of any course of instruction as they are standardised and therefore the same for each group of students.

Does sketching promote deeper levels of learning?

The short answer to this question is 'yes' and is supported by the overall good student marks. The benefits of sketching to enhance learning and comprehension are unequivocally clear (e.g. Novak and Gowin, 1984; Johnson and Reynolds, 2005). Nevertheless, it seems questionable whether students in the assessed module use sketching to its full potential. A concept sketch should be a simplified illustration of the main aspects including concise annotations. Constructive approaches are generally endorsed (Biggs and Tang, 2011) to promote deeper learning and in reaching higher cognitive levels of analyses and reflection. This in particular where students are actively engaged in finding an answer. Johnson and Reynolds (2005) therefore suggest to have students first interact with some prompting material such as photographs or animations about a topic before they construct a concept sketch that portrays the essential aspects. The advantage of student-generated concept sketches is that students have to actively engage with the material in order to create a meaningful sketch and therefore develop a sense of ownership of the learning experience. Science-education studies suggest that more effective learning takes place when the student's learning experience is student-centred where they explore, discuss and construct their own knowledge (e.g. Bonwell and Eison, 1991). Verbalising a concept and sketching are both constructive activities, and in conjunction promote a greater understanding and deeper processing of concepts and therefore level of understanding (Ainsworth and Loizou, 2003).

The implementation of concept sketches and its value in the teaching of the geology undergraduate module is therefore believed to be beneficial and in support of the students learning experience. However, students of this module and possibly in other subject areas rarely verbalise or discuss their concept sketches. Johnson and Reynolds (2005) point out that students may initially be very tentative of making observations or openly sharing them during class which is also confirmed by the teaching experience of this module. There is nonetheless a requirement to outline a meaningful concept sketch despite the fear that they might not see the same as their teacher or peer students. Thought provoking open questions can stimulate and encourage classroom discussions (McKeachie et al., 2002) and combined with a think-pair-share approach may ease some of these fears. The lecturer may also approach and help students to focus their inquiries as a roving tutor or facilitator during the initial stage of the discussion (Harvey and Harvey, 2013). It is important, however, that the facilitator leaves students sufficient time to answer their own and each other's questions and not to intervene significantly or by judging suggestions during the brainstorming process (Kindsvatter et al., 1996).

“The advantage of student-generated concept sketches is that students have to actively engage with the material in order to create a meaningful sketch”

The Coursework – exam discrepancy: what changes are required to increase student learning and performance?

On reflection the contrast between the students' performance in the coursework compared to that in the exam is evident. Furthermore, implemented changes after year-one teaching resulted in an increased performance in 7% of the students. Although, measuring the effectiveness of these changes by using data obtained through standard assessment may be questioned here by some. This is also in light of the overall lower average marks in both components in year two. Nevertheless, the presented data are interpreted here to indicate an increase in performance and overall learning.

The question remains whether the current teaching approach using sketching in order to promote more effective learning remains? According to van der Lugt (2005), sketching plays a positive role in the re-interpretation process which provides new knowledge, which leads to further re-interpretation. However, this requires the ability to interpret the observed information transforming this into a sketch and not simply to provide a copy. In the case of this study the student made a simple copy of the rock thin section without an interpretation or understanding of the involved processes (Figure 1a). Looking at Figure 1a more closely the illustration is, in the first instance, impressive. The students are instructed to provide details on individual rock components (minerals) and the spatial relationships between these (rock textures) which is clearly followed in the given example. Very fine details of the observed minerals and textural relationships are recorded but not interpreted and therefore not transformed into a concept (see Figure 1c). The most obvious explanation is that participating students need more help and guidance in constructing a meaningful concept sketch. Johnson and Reynolds (2005) emphasis that guidance in constructing a concept sketch should be provided at the beginning of teaching, initially generated by the instructor. The students are introduced to sketching during the course of this module but following more closely a learning-cycle approach as outlined above (Section 2.1; Lawson et al., 1989) may help increase the engagement of students to develop sketches through exploration, concept-introduction and a final application. Instructor-generated concept sketches early in the module may help the students decide what are important features to focus on and develop concept sketches.

Alternatively, the students leave the preparation to last minute and prepare all coursework material in one large session rather than during the term within the provided and timetabled slots. Experience of teaching the outlined module demonstrates that a significant number of students work in exactly this manner. Working in long stretches in the attempt to meet a pending deadline is affectionately known among time management types as 'death by deadline'. Some students claim that there is no point in starting projects until the last minute because they are convinced that their productivity is only inspired or sparked by the presence of an impending deadline. However, success of this approach is only guaranteed if the allocated time is kept free and not interrupted through a sudden and unforeseen change in circumstances. This could be a sudden illness or malfunction of the computer hardware or printer. This short-term preparation is not sufficient enough to provide the student with the necessary understanding or skills to process the complexity of the set tasks. The student's illustrations represent copies of the observed material and the critical thinking skills are not developed. This may explain or at least be in part responsible for the observed discrepancy in coursework and exam performance presented here. However, this hypothesis requires testing and as mentioned above best through a diagnostic test allowing comparison between years and maybe subjects relying on the same teaching and learning approach.

Conclusions

The benefits of sketching to enhance learning and comprehension are unequivocally clear forming a key component in learning and teaching of undergraduate geology students. Nevertheless, it remains open whether the students of Geology use illustrations to enhance the learning process and therefore their knowledge of the studied subject to their full potential. This was highlighted by the student performance between a coursework and exam component. Subsequent changes to the module, which included a refined outline of the given tasks and more detailed instruction on how to draw concept sketches, were implemented. It appears that these changes increased the student performance but an evaluation of this based on a critical assessment of the standard assessment test results alone seems insufficient. Student performance should be evaluated through a diagnostic test instead. This approach may also reveal whether student performance is related to the tasks (understanding and fully use concept sketches) or leaving exam preparations to the last minute.

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