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Constructivism and learning

Active learning and constructive alignment in the Surface Geochemistry course

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Introduction

The theory of Constructivism is largely ascribed to the Swiss psychologist and philosopher Piaget, who worked on cognitive development. Based on an earlier idea of knowledge being structured in frameworks, his work on the cognitive development in children let him to propose that they learn through two fundamentally different processes: they assimilate new information into existing frameworks without the frameworks being restructured or they accommodate information by restructuring the existing frameworks to conciliate them with the new information (Piaget, 1965). From the viewpoint of education, this idea entails that the actual construction of knowledge occurs within the learner him- or herself and that the background of the learner plays a critical role in the learning. These ideas have been adopted in many contemporary theories of learning (e.g.,Bransford, Brown, and Cocking, 1999; Biggs and Tang, 2007; Illeris, 2009).

In this work, I will focus on two aspects of learning: active learning and constructive alignment, both of which are rooted in the ideas of Piaget (Biggs and Tang, 2007). The idea of active learning gained widespread attention following the publication of the report "A Nation at Risk: The Imperative for Educational Reform" in 1983. This report resulted in numerous reports and articles, such as Cross, 1987, culminating in another report "Active Learning: Creating Excitement in the Classroom" (Bonwell and Eison, 1991), which concluded:

"[...] a thoughtful and scholarly approach to skilful teaching requires that faculty become knowledgeable about the many ways strategies promoting active learning have been successfully used across the disciplines." Bonwell and Eison, 1991, p. iii.

Central to the constructivist concept of active learning are that learners construct knowledge through activities using their existing knowledge as a base. The learning comes from structuring of transmitted information through activities to bring about changes in the way we perceive the world (e.g., Biggs and Tang, 2007).

The term constructive alignment stems from John Biggs' experiences with activity based teaching, which proved successful when correspondence existed between the intended learning outcomes, the learning activities and the assessment tasks (Biggs and Tang, 2007). Thus, if we want the students to learn about cooking, we are better off if we place them in a kitchen and allow them to eat what they are making before assessing their performance at a feast. Because the students' existing knowledge, their background, also play a factor in their learning according to the constructivist understanding of teaching, I will to some extend include this aspect in the constructive alignment as well. In other words, the intended learning outcomes has to be attainable for the students and should be aligned with their existing knowledge. Thus, a schematic representation of my extended constructive alignment could look like the one outlined in Figure 19.1.

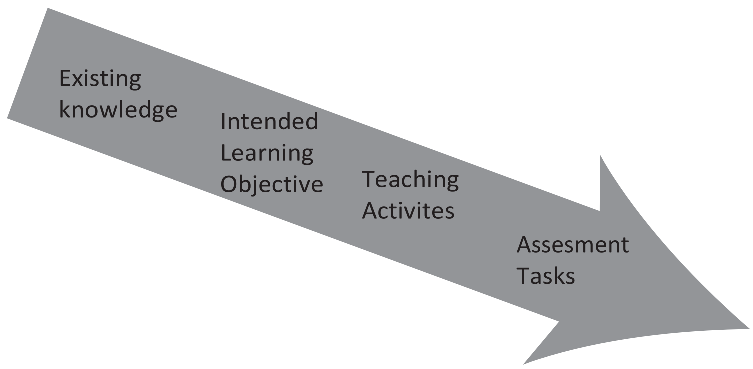

Fig. 19.1: Schematic representation of the course aspects that should be aligned.

The aim of this work is to analyse the active learning and the constructive alignment in my course Surface Geochemistry with the aim of identifying potential important improvements. In parts, the analysis will be based on feedback from students (both formal and informal) and my own observations during teaching. The formal student feedback stems from the electronic course evaluation conducted automatically at the University of Copenhagen and from oral feedback given in plenum at the end of the course, which was documented by one of the students as a written summary. Quotations from the plenum feedback refer to statements recorded by the student; these are paraphrasing of the actual discussion.

Overview of the Surface Geochemistry course

The course Surface Geochemistry is placed on the second year of the Chemistry bachelor program. The main purpose of the course is to give the students a qualitative and quantitative understanding of the most important processes taking place on surfaces in nature, because these are central to geochemistry, controlling largely the cycling of elements, for example. It is mandatory for students taking the education in Environmental Chemistry, but it attracts students from several other disciplines of science, ranging from Geology to Nanoscience, who come with highly variable seniority. In addition, PhD students from our section also take the course. This inhomogeneity in student background presents significant challenges. The course is given in English and the student workload is 7.5 ECTS. It is typically attended by 25-30 students. The course includes lectures, which are mostly given by me, as well as exercises in the form of manual calculations and computer modelling with a code called PHREEQC, which allows the students to simulate geochemical reactions. In the course structure, every lecture is followed by 2-3 hours of exercises, including breaks. In addition, 3 hours of "confrontation" are set aside for critical discussion of four Science articles, whose results are conflicting, and 6 hours of confrontation are set aside for a case study of their own choice, which is intended to result in a single page report.

I am the course responsible and have developed most of the teaching material except for the textbook and the articles used. Thus, I am free to change all aspects of the course.

Active Learning

As a result of the supervision during my University Pedagogic Course, I transformed all lectures after the first supervision day from "traditional lectures" of 45 minutes duration into "activity based lectures", where monologues from me are short (10 minutes or so) and separated by student activities of various kinds. My own impression was that these activity based lectures work well. The student feedback I have received express the same opinion, although the lectures became longer, taking time from the exercises (termed "calculations" in the quote):

"Godt med spørgsmål undervejs i forlæsningen, men dette trækker nogle gange forlæsningen ud, så måske skal man droppe nogle calculations så man får tid til små opgaver ind imellem" Feedback given by student in plenum at the end of the course, 2014

This year, I intend to change the remaining half of the traditional 45 minutes lectures into "activity based lectures". Although the activity based lectures are longer and will take time from the exercises, which are clearly also a form of active learning, I think that this is acceptable to some extend for several reasons. Firstly, my impression from feedback and my own observations is that the students manage to complete the exercises before going home, meaning that they have little preparation to do before the next teaching apart from reading. Also, the electronic evaluation in 2014 indicates that the time spent by the students was somewhat below what is expected for a 7.5 ETCS course. Thus, my plan is to take some time from the exercises to make activity based lectures that are intended to firmly establish an understanding of the important concepts in the students. Hopefully, this will allow the students to solve many of the exercises on their own with less feedback than they are getting at the moment. Nevertheless, the decrease in time allocated for exercises might mean that some students become stuck when solving them without teachers around to help. To alleviate this problem, I will stress that they can come to my office or that of the teaching assistants to get help almost any time.

Towards the end of the course, I had introduced a discussion session on the initial formation of solids from dissolved ions. The discussion session was based on four recent, high profile articles from the journal Science, which represent two conflicting viewpoints. Although Science articles are tough to read, the articles were largely based on core concepts in the course and I had prepared a reading guide, which specified what parts of the articles the students should focus on and defined terms and concepts that were new to them. To my surprise, many of the students had not read the articles. Nevertheless, we went through the session, spending time on reading and interpreting the data as well as on discussion. The session progressed well and feedback suggests that they enjoyed it:

"Diskussionen omkring de fire artikler var specielt spændende." Anonymous electronic feedback given by student in plenum at the end of the course, 2014

One of the reasons, that the session went well although the students came poorly prepared, was that the data presented in the articles was in a familiar appearance: it was either in the form of diagrams they were familiar with, or in the form of images and movies, which are vessels for information that most can relate to. However, I do want the students to work with the articles themselves, so that they can begin developing the difficult skill of extracting important information even when it is conveyed in condensed, written form. Next year I will stress that they really have to read the teaching material for this particular session.

Towards the end of the 2014 course, I asked the students to work alone or in small groups and use some of the tools they had acquired on a case study of their own choice. The results of their work were to be reported in a personal, single page report to give them the opportunity to improve their writing skills. From my impression of the reports and from the feedback, this case study was a success. On the list of good things, for example, one student simply mentions:

"Rapport" Anonymous electronic feedback given by student in plenum at the end of the course, 2014. "Rapport" was the term we used to cover the case study.

However, the exercise turned out to require a great deal of student feedback, meaning that students had to wait in line for me to have time to discuss. This occurred for several reasons and the problem can be mitigated in several ways. For example:

1. The application of the tools is not a straight forward matter and almost always involves reduction of the problem's level of complication by making simplifying assumptions. It is not easy for a student to see when an assumption is reasonable and when it is not. This is actually something that I want the students to understand better. Thus, I am contemplating having more, smaller exercises included earlier in the course to "train" them in making assumptions and critically evaluating

their impact on results. Also, this aspect should be embedded in the exercises.

2. Many students decided to work alone, meaning that the number of different subjects and problems I faced was high. To alleviate this problem, I plan to make it mandatory for the students to work in groups. Furthermore, this will allow the students to discuss the problem before asking for feedback, which I expect to increase the students learning. For example, Michael Prince points out that there is good evidence that cooperative learning increases the learning outcome at least compared to competitive learning (Prince, 2004). Student feedback also suggests that team work might be a good idea, although this opinion is not universal:

"Godt at arbejde sammen om problematikkerne, det gør ikke noget at man deler arbejdet op hvis bare alle har været med i overvejelserne" Feedback given by student in plenum at the end of the course, 2014

Thus, my conclusions regarding the active learning in the course is that it works relatively well in its current state, but that the activities could be improved and that they should be implemented in all lectures.

Constructive alignment in the course

First a couple of words on the students' existing knowledge and the constructive alignment. The highly variable background of the students presents a challenge to the teaching. To make sure that all have a platform for understanding the subjects I am teaching, the course is split in two in the first 2/3 of the first week, so that they can receive a crash course in either chemistry or geology, depending on their needs. This simple setup has worked surprisingly well. However, based on the student feedback, the crash courses should probably run an entire week, so that more subjects could be taught in a tailor made fashion to fit their background. This would mean that some aspects of chemistry that are currently being taught to the entire group could be given to the non-chemists only to avoid boring the more proficient, e.g.,:

"Kemien var lidt 'for nem' – fx. har vi allerede haft kurser i thermodynamik" Feedback given by student in plenum at the end of the course, 2014

On the other hand, the chemist could be more thoroughly introduced to minerals and solid state chemistry:

"Især mineralstrukturer skal uddybes yderligere og der skal være mere materiale tilgængeligt om emnet." Anonymous electronic feedback given by student in plenum at the end of the course, 2014

Thus, I plan to expand the crash course part to encompass one entire week.

To give an overview of the constructive alignment of the other aspects of the course, Figure 19.2 shows the overall intended learning outcomes, the learning activities, and the assessment tasks. In the figure, each intended learning outcomes have been marked with a differently coloured bar. In the learning activities and the assessment tasks, the coloured bars signify what intended learning outcome they target. Overall, there is relatively good alignment in the course. However, the red and orange text signifies elements that are not yet completely in place or are lacking altogether, i.e., places where there are challenges.

Two tasks will require a little more consideration: A. I ask the students to be able to make simplifying assumptions and estimate of the uncertainties involved in the simplification. This is not a straight forward thing to do, but I really want them to master this. Clearly, I should spend more time on this aspect in the activity based lectures and require them to use this knowledge in the exercises. In addition, I am considering using more time on the computer modelling. Because the software allows the students to simulate all the main reactions covered in the course, both in terms of thermodynamic equilibrium and reaction kinetics, it can be a formidable tool for the teaching. However, making input for the simulations to have them work as planned is somewhat complicated, in particular because I want the students to know what they are doing and be able to critically evaluate the results.

I have not yet quite figured out how to bring the students over the learning threshold of constructing sound inputs, but my current thoughts are to use more time on the simulations, both in the exercises and in the lecture activities, focusing on having the students become more slowly familiar with the program, so that i) basic concepts can be thoroughly understood before moving to more advanced capabilities and ii) the results of the simulations can be much more thoroughly explored. My intuition tells me that a more thoughtful use of the modelling program can improve the learning outcome of the course significantly and can provide them with a tool that they might be able to use to great effect later in their studies or careers.

B. I have not been able to find a textbook that covers the subjects of the course in a pedagogic manner, that efficiently facilitates understanding the topics. Consequently, I am still searching for a really good textbook. The

Intended learning objectives	Teaching activities	Assesment tasks
Knowledge	*Activity based lectures*	*Tasks in two written exams*
- understand the control on the composition and structure natural surfaces	- Shorter descriptions of theory, separated by student activities. Critique of models and theories	- description of surface structure and composition and analysis of changes
- understand and apply thermodynamic and kinetic theories in the descriptions of geochemical systems	- Student activities where they apply or discuss theory	- assingments requireing thermodynamic or kinetic theory
Competances	*Exercises*	*Tasks in two written exams*
- application of qualitative and quantitative concepts in geochemistry, including the use of the computer code PHREEQC for geochemical modelling.	- Quantitative hand calculations and computer modelling and qualitative interpretation of results. Evaluation of results. Construction of diagrams to represent results graphically. Writing of one detailed figure caption for every hand calculation.	-quantitative and qualitative assigments using hand calculations and computer modelling.
- application of simplifying assumptions and estimation of the uncertainties involved in the simplification	- Identification of assumptions inherent in the calculation and modelling and discussion of their impact.	- Discussion of the results and the assumptions made during the assignment
- construction of diagrams typical to geochemistry		-some assigments ask for the construction of diagrams.
Skills	*Discussion session and short project*	*Report production (formative feedback)*
- application of knowledge and competences in 1) critical evaluation of scientific communications and own geochemical modelling, and 2) solving of more complex geochemical problems.	- Critical discussion session on four science articles representing two contrasting viewpoints - Selection of a more complex geochemical problem for quantitative analysis. Writing of a one page report.	- *feedback on the scientific qualities of the report*
- increased awareness of scientific reading and writing	- Reading of text book and articles	-*feedback on the textual qualities of the report*

Legend

Red text: Problematic element Orange text: Not having the wanted extend/quality, but improvements have been made

Fig. 19.2: Overview of the elements of the intended learning outcome, the teaching activities and the assessment tasks (including formative feedback). The intended learning outcomes have been assigned coloured bars. For the teaching activities and assessment tasks, the coloured bars signify what intended learning objectives are targeted. Thus, the teaching activity "Students activities where they apply or discuss theory" contains aspects of both intended learning objectives in the category "Knowledge". The red and orange text signifies elements that are not yet completely in place or are lacking altogether.

first couple of years I used one book, but as one student mentions in a course evaluation, the book is awful. In 2014, I changed to another book, which I have found truly useful in my research. However, this book is nowhere near as pedagogic as one could wish. In fact, many of the students from this year reported that they had cut down on the reading in the course texts altogether because they found the textbook so inaccessible. This attitude was carried over into the reading of articles, meaning that more time had to be devoted to the discussion session than originally planned. Surprisingly though, the students did rather well, suggesting that a textbook is perhaps not critical to achieving the intended learning outcomes. Thus, the problem about the book might be an opportunity: Perhaps it would be possible to have other means of preparation that are far more effective. However, this is a change I have to consider very carefully and I currently do not know exactly why they abandon reading the book. My impression from talking to the students is that the book is poor at providing context, so I plan to either supplement with additional material or to change to another, more suitable book (although this has so far proven hard to find). Eventually, I might end up compiling a compendium with smaller texts from different authors, so that it will cover the subjects in a better manner. However, it might be difficult getting all these different texts aligned in terms of nomenclature, etc. Also, such texts aimed at second year students are not easy to find. Thus, finding a solution to this problem will be on the top of my list in the time to come.

Peer feedback on project

As part of the assignment, a colleague provided feedback on this report. Although he mainly had suggestions to the textual aspects, he found the idea of having the students discuss very advanced scientific articles presenting conflicting view points an exiting, albeit demanding, manner of teaching. Based how the discussion went, I agree with his viewpoint - but if the students were nudged gently in the right directions, they were able to figure many things out themselves. My impression was that they learned quite a bit and that their confidence in their own abilities increased. I am considering having more of such discussions. For example, I have just found several errors in one of the articles, which relate directly to the content of the course. In fact, I do not think I would have noticed the errors had I not been teaching the subjects I do. I think it would be an interesting exercise to have the students identify the errors, so that they can see that scientific work may well be wrong, even when published in the most respected of journals. Finally, he was sympathetic to my problem with the textbook, suggesting with a smile that I had to write my own. I would certainly like to, but I do not currently have the time for such an effort.

Conclusions

Analysis of the active learning in the Surface Geochemistry course indicates that it works relatively well, where it is implemented. The students are active and they enjoy the discussions. The data do, however, not allow me to evaluate if it improves the learning outcome. In general, the course is constructively aligned. However, several aspects exist that could be improve on. For example, the students should be more engaged in making simplifying assumptions and discuss their implications, because this is an important intended learning objective. Finally, the textbook does not gain wide acceptance from the student and should be replaced with other teaching material. In general, this type of analysis has proven a good tool for understanding shortcomings in the course structure as a whole. In the upcoming revision of the course, I will apply the same procedure on the individual elements of the course, i.e., activity based lectures, exercises, etc.

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