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Lessons Learned - Constructive Alignment meets Lean & Green Production

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Abstract

Die Qualität einer Lehrveranstaltung zeichnet sich neben den Lehrinhalten insbesondere durch die Elemente des Constructive Alignments aus. Dieses umfasst die drei gleichwertigen Bestandteile: Lernziele, Lernumgebung sowie Methoden und die anschließende Prüfung. Zum Gelingen einer ganzheitlich geschlossenen Lehrveranstaltung ist eine hinreichende Planung erforderlich, welche ein Ineinandergreifen dieser Bestandteile ermöglicht. Im Rahmen der Umstrukturierung der Lehrveranstaltung „Lean & Green Production" an der Leibniz Universität Hannover wurden die Erfahrungen gesammelt, welche Bestandteil dieses Papers sind. Die Anpassung der Lehrveranstaltung hinsichtlich des Constructive Alignments hat gute Ergebnisse erzielt und ist auf positive Resonanz gestoßen.

In addition to the course content, the course's quality is characterised mainly by the elements of constructive alignment. This comprises the three equally important components: Learning goals, learning environment, methods, and the subsequent examination. For the success of a holistically closed course, sufficient planning is necessary, which makes an interlocking of these components possible. The course adaptation concerning constructive alignment has achieved good results and has met with a positive response. In restructuring the course "Lean & Green Production" at the Leibniz University of Hanover, the experiences were gathered, which are part of this paper.

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1. Components of Constructive Alignment

According to the Constructive Alignment teaching model, learning goals, setting, and assessment components appear as equal elements of courses. The primary intention is to harmonise their contents and interactions. For example, the setting of a course should be designed through methods in a coordinated sequence to align with the learning goals. Likewise, it is essential to unite the examination requirements with the learning goals to create a holistically coherent course. [1]

In order to implement constructive alignment, sufficient instructional planning is required before the start of the semester to develop a uniform and coordinated concept. Likewise, planning must consider the design for a purely face-to-face semester and the transition to a concept for hybrid or purely digital teaching. In this respect, it makes sense to weigh the options early to avoid last-minute changes in the current semester. This applies in particular to the setting, as the teaching methods for interacting with students change and require preparation for the transition.

The Institute of Production Systems and Logistics (IFA) implemented this concept in the *"Lean & Green Production"* course. For this purpose, a complete linkage of the three components was implemented as part of a funded project. The project was made possible by a funding program to improve teaching at the Mechanical Engineering Faculty of Leibniz Universität Hannover (LUH). Students evaluated it in the current semester and in the context of accompanying advanced teaching training, including observation. Most of the experience gained in the process has already been implemented in the current semester and is the subject of this paper.

2. Learning goals in the event

The course *"Lean & Green Production"* has been redesigned for the summer semester of 2022, but its contents have been part of the curricula of the engineering programs of the Faculty of Mechanical Engineering for a long time. The course has approximately 60 participants per semester. As an elective module, the course can be taken by Master's students of different courses and as a compulsory elective module by Bachelor's students of the "Sustainable Engineering" course. Due to diverging theoretical prior knowledge and practical experience of the participants, e. g. through internships or working student activities, the definition of common learning goals was elementary as a consensus.

Determining the learning goals is an essential prerequisite for successfully implementing Constructive Alignment. It forms the basis for the selection of the setting and the examination. The learning goals are derived from the overarching mission statement (guidline goals, broad goals) as detailed goals. [2]

A **guideline goal** describes the intention of an education or a study program. The following central guideline goal was described for the event under consideration:

An essential qualification goal of engineering science courses at LUH is to enable students to evaluate processes based on a scientific-systematic approach. This is achieved through an analytical understanding of complex issues to identify socio-technical design options.

The **broad goal** derived from the guideline goal makes concrete reference to the course. In this exemplary case, this was directly linked to cognitive learning goals:

Starting with considering the philosophy of lean production and the development of lean production systems, the fundamentals of production system planning are covered, taking into account the megatrend of sustainability. The focus is on analysing, evaluating and selecting lean methods for specific use cases.

The **detailed goals of** the course modules are explained at the beginning of each course date and refer to one module each, which consists of a combination of a lecture and exercise unit. Depending on the module content, different cognitive learning goals are described, which build on each other. The basic knowledge is taught in 90-minute lectures on eleven dates. These lectures address the cognitive learning goals of level1 1 (remembering) and level 2 (understanding). For example, after the introductory module, students should be able to explain the forms of waste in production systems. A classification of the cognitive learning goals can be found in Figure 1 below.

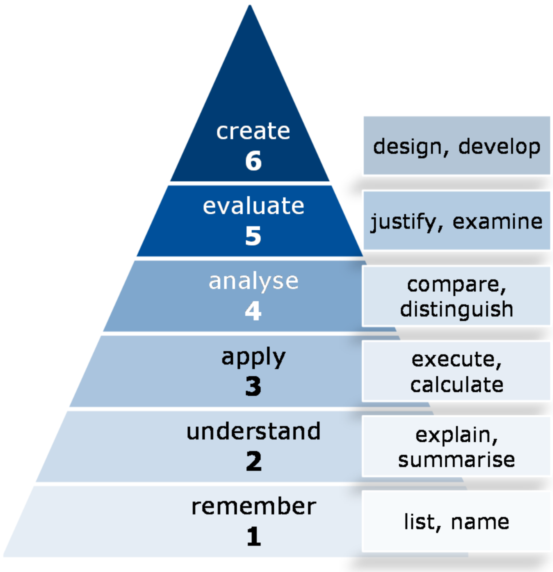

Figure 1: Taxonomy of cognitive learning goals [3].

In the subsequent 45-minute exercises, the content is deepened as students apply it (learning goal level 3) and analyse it (learning goal level 4). During a one-day workshop in the advanced part of the course, students learn about the cognitive learning goals of levels 5 and 6 in groups (approx. 15 participants). [3]

A detailed description of the workshop takes place in the following chapter 3.

3. Learning environment and methods

The teaching philosophy of the course includes integrating practical parts into the course and thus follows the motto *theoria cum pra*xi (engl.: theory and practice) of the LUH. Furthermore, frontal teaching is avoided wherever possible and instead replaced by activating teaching methods (e. g. by footnote presentations[1] with practical examples instead of slide presentations by the lecturers). Students receive stimuli from industrial applications through guest lectures, which provide insight into the complexity of implementation in actual industrial companies. In addition, the practical components are represented by business games on production system design in the exercise sessions. The assumption of different roles in the business games and the staging of workshop formats are intended to impart interdisciplinary competencies. The *concept of competence* can be understood as *"a combination of knowledge and skills in coping with action requirements"* [4].

The course is designed to provide students with methodological competencies for later use in the profession (industry, science, consulting) and technical competencies. An essential part of the course is participating in the 1-day workshop *Production Trainer* in groups of about 15 participants. The workshop takes place in the institute's IFA Learning Factory, shown in Figure 2. The simulation game *Production Trainer* takes up the workshop idea from the exercises already completed in the courses and offers the students the opportunity to analyse a production system independently as a group, to plan it subsequently and finally to implement it directly. Following this procedure, they can run through the optimisation cycle using lean methods over several rounds of the game and thus acquire teamwork, problem-solving, moderation skills, and technical competence.

Due to its structure based on the principle of changeability of assembly systems, the IFA learning factory allows the mapping of diverse business game scenarios in the context of lean production and can thus be adapted to specific groups. In this context, students should also learn to operate in a constantly changing environment. The term *changeability* describes the efficient performance within defined limits (flexibility) plus the potential for structural adaptation (transformability) of systems that can be activated when necessary [5]. The course is intended to enable students to be universally deployable in later professional life (personnel changeability) and to familiarise themselves quickly with new topics.

4. Examination

Due to the planning uncertainty in the winter semester of 2020/2021 regarding implementing classroom examinations at LUH, the course examination took place for the first time as an

[1] Reproduction by students of the brief definition of a pre-assigned technical term in a few sentences once the instructor has used it in the lecture.

electronic examination via the teaching platform LUH-Ilias. The initial effort to create the exam questions, as well as the smooth processing of the exam via a digital teaching platform, was excellent. The exchange of experiences within the institute, with the Mechanical Engineering Faculty and with institutes of other faculties of the LUH can be regarded as an essential lesson learned. Only this made the short-term conversion of the examination medium possible. The consultation with other examiners at the university in the context of teaching exchange formats has thus contributed significantly to this change. The experiences with the examination format and the teaching platform were considered in the following semesters when implementing the digital examination (open-book principle). The requirements of past exams were focused on knowledge reproduction, whereas the digital exam contains a more significant proportion of application tasks. The examination format has since been retained. It contains single- and multiple-choice questions, free-text and cloze-text application tasks for calculations and process analyses.

Figure 2: Photo of the working environment for implementing the "Production Trainer" business game in the IFA Learning Factory.

The change in the examination format also resulted in a change in the question's content and the student's learning behaviour and has not yet been taken into account in the implementation of the course. The change from memorisation to comprehension and transfer questions through the examination design must continue to be strongly supported. This circumstance needs to be eliminated or mitigated through Constructive Alignment. Reference to the upcoming digital exam was made early in the course of the preparation. A comprehensive exam session is intended to familiarise students with the teaching platform and the type of questions. The students will be given a sample exam under natural conditions that can be repeated as often as desired and discussed together at the beginning. As part of the "Pro Teaching" program of the university's internal teaching development, the quality of the examination questions could be increased and the misunderstandability of formulations reduced.

This must be evaluated after the examination and adjusted regarding the examination requirements concerning the course's learning goals.

5. Evaluation and experiences from the current semester

It was integrating a semester consultation hour to actively incorporate student feedback allowed for slight adjustments to the concept for the current semester's outstanding deadlines. This allowed for direct student feedback on the use of the footnote referees addressed in Chapter 3. Due to the high number, these have significantly shifted the time frame of a lecture date. The lesson learned from this is more targeted scheduling in the future by setting presentation limits. In addition, the content must be suitable for applying the methodology. In this case, this requirement was not readily met, as the students were not dependent on the explanations in the footnote presentations due to the lecture notes and, according to their statements, did not have to follow the presentations attentively.

It should be noted that even small changes in the course can significantly impact the transfer of knowledge. This does not necessarily require a change in the lecture content. The interaction with the students and the integration of the practical units will be evaluated positively according to their own experiences and the students' feedback and should be maintained for the coming semesters. The current examination in the form of a written exam (regardless of the medium) can almost exclusively consider technical competence and only little methodological competence. This is difficult because it represents an inconsistency in the Constructive Alignment framework throughout. Implementing the other Constructive Alignment elements has worked well according to student feedback and teaching observation.

6. Conclusion and outlook for future semesters

The concept of Constructive Alignment has achieved good results and increased the quality of the course as well as the motivation of the students. Therefore, the implementation of the concept will be continued in the following semesters. It has been shown that even small changes in knowledge transfer can increase the attractiveness of courses. However, the methodology must be chosen depending on the respective detailed goals (cf. Chapter 1).

In the future, the learning goals are to be formulated even more precisely so that the method selected for the respective contents of the lecture can be made more precisely. In addition, the experiences of lecturers and observers and the students' feedback can be used for the ongoing teaching design. In the future, students will also be offered the opportunity to participate in research studies in the IFA Learning Factory in the area of production system design and learning behaviour so that they can also deal with the practical scientific side in addition to the practical industrial side. Initial results have already been achieved in a preliminary study [6].

Integrating guest lectures suitable in content and methodology to strengthen the guiding principle of *theoria cum praxi represents* a core task for the upcoming semester planning. The current guest lecture is interesting in content and popular with students but does not fit naturally into the Constructive Alignment of the course and is not a component of the exam. The current exam has the potential to be expanded to include additional sub-credits, thus providing more focused control over aspects of methodological competence. The design of questions requires special care in the area of knowledge reproduction in an open-book exam. If necessary, these could be integrated into the workshop and thus provide an opportunity to check the cognitive learning goals *Assessment* and *Creation* (learning goals levels 5 and 6, cf. Figure 1).

Course planning and course teaching concepts are often based on autodidactic knowledge. For this reason, participation in internal university offers to improve the quality of courses is recommended for all persons involved in university teaching. The exchange with lecturers from other departments is equally advisable, as they often have a methodologically influenced perspective on the course instead of a purely content-based one.

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