Lessons Learned 2, 1 (2022)
Submitted: 05.04.2022
Accepted: 07.06.2022
DOI: https://doi.org/10.25369/ll.v2i1.38
ISSN: 2749-1293 (print); 2749-1307 (online).

Promotion of self and methodological competence in the digital biomechanics practical course

B. Kruppke*

Chair of Biomaterials, Institute of Materials Science, Faculty of Mechanical Engineering, TU Dresden

Abstract

Mit der Anpassung der Hochschullehre an den digitalen Raum wurden verschiedene Konzepte für Vorlesungs- und Seminarformate entwickelt, umgesetzt und evaluiert. Besondere Aufmerksamkeit wird deshalb nun Formaten gewidmet, deren Fokus auf praktische Lernerfahrungen gerichtet ist. Es ergibt sich ein Widerspruch aus dem Vorhaben Praktikumsveranstaltungen in den digitalen Raum zu verlegen, was im Folgenden durch die Erläuterung bisheriger Praktika in der Professur für Biomaterialien der Technischen Universität Dresden verdeutlicht wird.
Aufbauend auf dieser Betrachtung wurde eine Lernwerkstatt zum Thema „Biomechanik im Alltag“ unter Berücksichtigung der Limitationen und Möglichkeiten des digitalen Raumes entwickelt. Das Ziel der digitalen Lernwerkstatt ist eine kompetenzorientierte praktische Lernerfahrung zum Erwerb von Selbst- und Methodenkompetenz, im Vergleich zur Fachkompetenz-getriebenen Präsenzlehre. Die Lernwerkstatt wurde im Modul Werkstoffwissenschaft (2. Semester) als synchron-digitales Praktikum mit asynchronen Aktivitätsphasen durchgeführt. Zunächst wird die an Projektmanagementansätze angelehnte Durchführung der Lernwerkstatt erläutert. Daraus ergab sich eine individuell vollzogene Projektbearbeitung durch die Studierenden. Die abschließenden Erkenntnisse aus der Betreuung des Lehrformates führen zum Ausblick auf eine Lehrveranstaltung, die die Elemente des Projektmanagements mit den Fachinhalten verknüpft.

With the adaptation of university teaching to the digital space, various concepts for lecture and seminar formats have been developed, implemented and evaluated. Special attention is therefore now being paid to formats whose focus is on practical learning experiences. A contradiction arises from the plan to move internship events into the digital space, which will be clarified in the following by explaining previous internships in the Chair of Biomaterials at TU Dresden.
Based on this consideration, a learning workshop on the topic of "Biomechanics in everyday life" was developed, taking into account the limitations and possibilities of the digital space. The goal of the digital learning workshop is a competence-oriented practical learning experience for the acquisition of self- and methodological competence, in comparison to subject competence-driven classroom teaching. The learning workshop was implemented in the Materials Science module (2nd semester) as a synchronous digital practical course with asynchronous activity phases. First, the implementation of the learning workshop based on project management approaches is explained. This resulted in an individually completed project processing by the students. The final findings from the supervision of the teaching format lead to the outlook for a course that links the elements of project management with the subject content.

*Corresponding author: benjamin.kruppke@tu-dresden.de

1. Introduction

Lectures and seminars with online tools, in hybrid format, via synchronous web meetings or asynchronous work assignments, with inverted classroom [1–3], annotated PowerPoint slides, scripts, or audio files - all of these are state of the art in university teaching today.

The transformation of hands-on learning experiences is much more difficult to realize in this context, as individual digital lab courses are very strongly linked to the respective subject areas. For example, Lab@Home approaches with individualized courses in a computer lab can be implemented primarily for programming tasks, CAD courses, or modeling [4]. Practical experiments in the university context, on the other hand, often require complicated equipment or expensive measuring devices. These can be provided, for example, by mobile engineering cases [5]. However, again, the limits of the experiments and the number of students are quickly reached.

A low-threshold approach is represented by experiments that can be performed by students themselves at home using available components. It was shown that the students had the opportunity to work with the experiments over several weeks, to carry out extensive series of experiments, and thus to gain a deep understanding of the content aspects [6]. The intensive engagement with the method itself and the support of individual learning experiences can thus compensate for digital and distance learning limitations. In addition, comparative observations of individual students' results can provide another dimension of professional assessment [6].

The development of a learning workshop on the topic of "Biomechanics in everyday life" takes into account the limitations and possibilities of the digital space, with digital communication tools being used to coordinate and compare the individual experimental results of the students. Basically, the learning workshop is carried out according to guidelines of agile project management [7–9]. This is reflected above all in the iteration steps and the defined time limits of the project process. The different prerequisites in the self-study phases are also subject of the students coordinated planning of the learning workshop, whereby the presence of a cell phone or a similar portable device with acceleration and position sensors is a prerequisite. The learning workshop was designed and implemented as part of the materials science module (2nd semester) as a synchronous digital practical course with asynchronous activity phases. Here, synchronous teaching means that the teacher and the students participate in a course at the same time in a defined time frame, while asynchronous teaching is understood as the students' engagement with provided learing content independent of location and time. In future, a transfer of this format to the module Biomechanics (8th semester) is intended.

For a better classification of the subject-specific requirements for practical courses, laboratory experiments and experimental lectures, the sequence of classical practical courses in the field of biomechanics or biomaterials is first explained. As a result, the digital biomechanics practical course is planned in the form of a learning workshop with a shift in the primary focus from teaching of technical skills to the development of self and methodological skills.

2. Face-to-face lab courses

Within the framework of the practical course, two teaching formats are carried out, the classical laboratory practical course with a given procedure or the more creative learning workshop in the Chair of Biomaterials. The lab course focuses on the acquisition of technical and methodological competence. For this purpose, there is usually a very specific task, which is closely linked to the lecture. The execution of the practical course requires the students' special knowledge to be able to work on the problems independently and appropriately and to assess the results (specialist competence according to [10]). This requires the ability and willingness of the students to apply certain working methods (methodological competence, [10]).

Thus, classical lab courses on the subject of biomechanics focused, for example, on the analysis of the material properties of biological materials in order to gain information on the mechanical properties, e.g. using a piece of bone. Thus, according to a buttom-up approach, i.e. starting from microscopic dimensions and molecular properties to deduce macroscopic composite properties, the fibrillogenesis of collagen as a basic component of bone was analyzed by means of UV/Vis spectroscopy and atomic force microscopy. Based on this, bone remodeling was characterized by degradation and cell experiments. This is based on the subject-oriented and methodological learning objectives that students are able to perform simple laboratory tasks and measurements. In addition, they will be able to explain relationships between bone components and their formation conditions and the degradation processes. Due to the actual tasks and the tight schedule of the lab curse, the students are generally not encouraged to contribute their own creativity or approaches.

The concept of learning workshops as a practical teaching format focuses on the students' independent research-based learning. As a subject-related learning objective, the students should be enabled to develop a concept for the analysis or imitation of a biological model. This requires that they independently agree on a strategy as a group and finally jointly prepare and present their results. In the technical context, the students learn to communicate in the group, i.e. to express their ideas in a comprehensible way and to listen actively both to criticism and to ideas. They have to learn, to jointly plan tasks and, if necessary, taking a step back themselves, which strengthens their social competence for constructive cooperation.

In most cases, a vaguely formulated task or question serves as an incentive to activate the creativity and curiosity of the students. By providing an extensive range of materials and methods as well as a space or platform for exchange between the students, a work plan is first developed [11]. The students are left to their own devices. The teacher is available as a dialogue partner and learning companion, without directly interfering in the student activities [11].

The established procedure is based - in accordance with the theoretical concept - on the direct involvement of the students with an impulse object (e.g. a crab shell or chicken bone) or a question (e.g. What makes the bone so resilient?). The available spectrum of methods is made accessible through a laboratory tour (at the Max Bergmann Center of Biomaterials, Institute of Materials Science).

Without a strict subject-specific instruction, the concept of learning workshops shifts the focus of competence acquisition more toward self-competence and social competence. This naturally places greater demands on the agility and improvisational talent of the teachers. However, the students' independently acquired technical and methodological competence can be particularly intensified in this way, albeit at a somewhat lower level.

3. Practical courses in the digital space

The explanations of the face-to-face lab course and especially the learning workshops indicated, that the transfer of learning objectives and the acquisition of competencies through a practical course in the digital space is particularly difficult.

Various digital teaching formats with practical relevance were primarily aiming at teaching technical skills. For this purpose, experiments were recorded as videos and made available to the students (Fig. 1a). Furthermore, experiment lectures were conducted as synchronous events with web-based interaction possibilities (chat, shared whiteboard, voting) by students and lecturers (Fig. 1b). [12]. In addition, following a classical practical course sequence, preparatory tasks were provided to students as pdf scripts, followed by asynchronous "presentation" practicals, produced by lecturers in advance. Here, the experiment execution and results are prepared in the form of presentation slides supplemented by short video sequences (Fig. 1c). The aim is to make the execution of the experiment and the acquisition of measured values as comprehensible as possible, so that the evaluation of the data provided can be carried out by the students in a final practical protocol.

As a result, however, it becomes apparent that the practical learning experience cannot be compensated by the high level of engagement in video creation and experiment demonstration. This was confirmed by student feedback with quotes such as "prefer lab course on site" and "too much to read" about the accompanying material provided. It seems that the incentive for lengthy practical course preparation with detailed scripts decreases if these courses are subsequently available as a video or results presentation and can also be played through to the end more quickly. Furthermore, the training of students in the context of qualification works at the chair is also associated with greater effort, when practical experience in the laboratory is missing during studies, which resulted in a plan for more practical courses in the Chair of Biomaterials.

Fig. 1: a) Photo from a video recording from the cell culture lab, b) Video still from an experiment lecture, c) Experimental results as presentation slides (photos and time-lapse video) for evaluation by students.

4. Agile project management in university practical courses

Following agile project management, the students are confronted as a team with a problem that is outlined by several scenarios. Thus, they can decide for themselves which partial aspects they would like to work on, how to design a solution and which means are necessary and feasible for this. The lecturer is exclusively responsible for supporting the group organization (providing a communication platform, data exchange, etc.), for mediating any planned investigations and in conflict situations between the group members.

The organization of the group, such as a division into smaller expert groups dealing, for example, with theoretical principles, technical implementation and the consolidation of individual findings, is the responsibility of the group itself, for which a group leadership position is to be determined by the group members.

The project processing takes place in fixed time intervals, whereby a work plan for the current interval is always created at the beginning, which provides a presentable result as quickly as possible. By jointly presenting the result to the lecturer, the students quickly receive feedback on the requirements that still need to be implemented or new ones that arise. These are included in the work plan for the next interval (according to the prioritization by the students) and implemented.

With the help of this concept, students are given greater responsibility and freedom, which encourages creative and flexible problem solving.

After implementation it became apparent that agile project management can be seen as a learning objective so that the students are already familiar with agile methods, the personnel roles, artifacts and events provided therein for their later work and may transfer these to other departments.

5. The digital learning workshop

For the digital learning workshop, the concept was applied as follows. The primary goal was to redesign the practical course as an individual learning experience, so that the central points are 1) students autonomy, 2) the use of commonly available tools and methods and 3) a topic related to materials science (specifically: biomechanics). This was implemented by the students by deciding to record motion sequences of everyday activities using the sensors in cell phones.

Individual work should be possible, so that the group result is only achieved by digitally merging the individual results. The students should be able to participate in the digital workshop alone and equally.

A digital learning space (e.g. BigBlueButton, Zoom) provided on a scheduled basis was used by the students for exchange within the group, for designing experiments and for discussing results, while the lecturer was only available as an advisor.

Procedure

A short explanation of the learning workshop concept and the topic description (biomechanics) takes place during the kick-off event. The complexity of the acquisition of biomechanical parameters is explained by the teacher and reference is made to the various aspects: from cell structure, to biomaterial components, to sports biomechanics.

In the following, the students work out their plan for recording of biomechanical processes in everyday life as well as a work plan for the first interval. Synchronous consultations (every 2 weeks) serve to harmonize the individual tests and discuss the measurement results. From this, further methods are worked out in the following intervals in order to harmonize the individual results and to record them in a comparable way. Finally, the individual results are evaluated as a group result with transfer of the kinematic measured values to the dynamic load situation of the body as a presentation.

Results

Since biomechanics in the present case deals with the human musculoskeletal system, a way to characterize it had to be found first. For this purpose, the students chose cell phones as a commonly available measuring device. The motion sensors were recorded and read out using the app phyphox® (available for Android and Apple) [13,14].

Various potential motion sequences were noted by the students on a digital whiteboard and a selection was made. This selection was specified in the second interval after a first check of the recorded data and suitable boundary conditions (motion sequences, cell phone positioning). In addition, the possible characteristic parameters for data recording as well as the recording boundary conditions (number of movement repetitions, weights, pauses) were collected (Fig. 2).

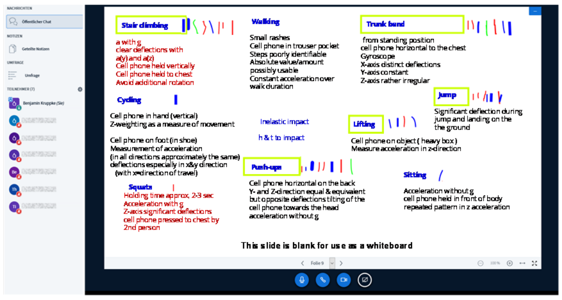

Fig. 2: Shared whiteboard: parameters and matching (vertical lines) for the motion sequences to be recorded (stair climbing, trunk bending, jumping, lifting, push-ups).

In the second interval, a platform (Google Sheets) was also selected for collaborative data visualization and analysis. A subgroup of the students took over the normalization and the staggered plotting of the data of all members.

In the third interval, the motion sequences of all students were recorded in 8-fold repetition with the phyphox function "acceleration without g". After an initial data comparison, the individual movement data were normalized to the respective total duration based on characteristic maxima or minima of the first and last repetitions (Fig. 3).

The comparison of individual data presented a particular challenge, as even slight deviations from the protocol resulted in different characteristic acceleration patterns of individual movements. Thus, in the last interval, the students scheduled a final outdoor presence session, which was conducted in compliance with the Corona protection measures. Here, selected sequences were recorded by all students simultaneously and under controlled conditions. The added value of the group activity was evident from the significantly more uniform movement curves. It should be noted that a purely digital approach to conducting the digital learning workshop would also have led to a meaningful result in terms of biomechanical movement sequences in everyday life.

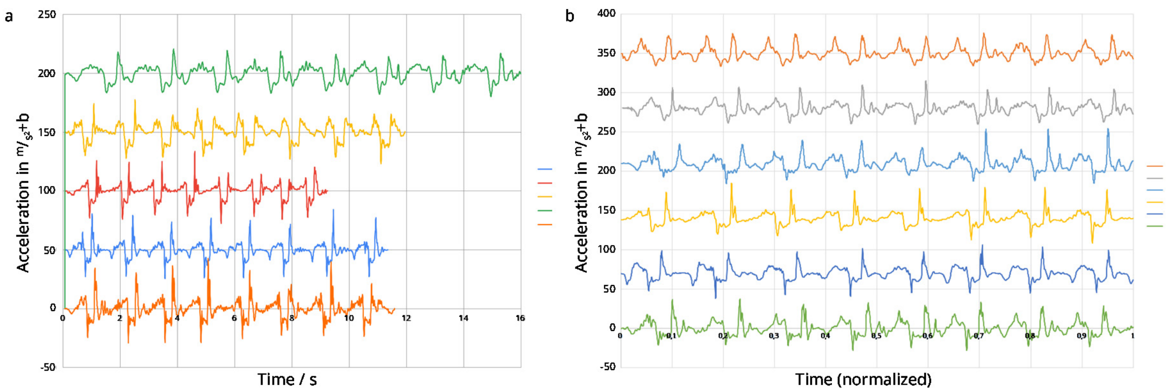

Fig. 3: Jump acceleration data of the students (8 repetitions each): a) raw data, b) normalized to respective total durations.

In addition to the technical component of the face-to-face meeting, the students were able to demonstrate the self-competence they had acquired through the measurements they had previously performed independently. For example, they pointed out to each other possible ways of improving the movement sequences, independently selected the execution locations and aids, and coordinated the timing. All students mastered the technical handling of the mobile phone-based measurement data acquisition without any problems. The evaluation and discussion of the results, as well as their presentation as a group, were also carried out to an extremely high standard considering the early semester of study.

In the context of further practical groups, a stronger focus is to be placed on the final transfer of the measured values to the load situation of the body. Here, the rapid transition from the determination of the movement sequences to the measurement procedure resulted in a neglect of the later significance and the inclusion of further possible measured values or methods. Thus, the students decided not to evaluate the stair climbing as well as trunk bending because of the limited informative value.

The implementation of the agile project execution led to a high level of commitment of the students. This was evident in the creative and time-consuming test phase of the measured data acquisition of various motion sequences.

In addition to the online meetings, all students carried out measurements of their movement sequences and independently entered the data into the shared table. Due to the agile, i.e. step-by-step implementation, this took place several times under changed boundary conditions (specifications that the students gave themselves for their measurements). The data of all students for all movement sequences were always inserted and evaluated according to the time specifications. Even in later project intervals, the comparability of the individual results was improved with great effort.

The insights gained during the digital learning workshop now serve as the basis for the redesign of various modules. These will be even more strictly aligned with the requirements of agile project management. Although the modules will be held in person or in a hybrid format, the experience gained, will make it possible to switch directly to the digital space if necessary. For these new modules, the digital lecture recordings produced during the last “Corona” semesters are made available in the sense of an inverted classroom approach in order to work on project tasks iteratively and creatively. The basic knowledge is thus applied instantly and the importance of this knowledge can be experienced by the students directly in the project.

6. Lesson learned

- Videos and interactive experiment lectures cannot replace hands-on learning experience (limited methods)
- Individually feasible learning workshops with cell phone as measuring device are comparably easy to implement (with high acceptance)

- Students acquire a high level of self-competence in learning workshops, which is reflected in active participation
- Digital teaching concepts can be more easily converted to face-to-face events (with PCs, if necessary)
- Agile iterative project processing promotes commitment and creative approaches to solutions

Acknowledgement

In the context of course planning, I would like to thank Professor Dr. Hans-Peter Wiesmann, Dr. Thomas Hanke, Dr. Ute Bergmann, Dr. Sabine Apelt and Dr. Christiane Heinemann for their collegial support and lively exchange.

Literature

[1] B. Kruppke, Der Mix macht's – Asynchron, synchron, inverted … von der Folienvertonung bis zum Experiment, Lessons Learn. 1 (2021) 1–12. https://doi.org/10.25369/ll.v1i1/2.2.

[2] N.T.T. Thai, B. De Wever, M. Valcke, The impact of a flipped classroom design on learning performance in higher education: Looking for the best "blend" of lectures and guiding questions with feedback, Comput. Educ. 107 (2017) 113–126. https://doi.org/10.1016/j.compedu.2017.01.003.

[3] A. Roehl, S.L. Reddy, G.J. Shannon, The Flipped Classroom: An Opportunity To Engage Millennial Students Through Active Learning Strategies, J. Fam. Consum. Sci. 105 (2013) 44–49. https://doi.org/10.14307/jfcs105.2.12.

[4] J.-O. Joswig, F.M. Arnold, Lab@Home: Individualisierte Computerpraktika, Lessons Learn. 1 (2021) 1–8. https://doi.org/10.25369/ll.v1i1/2.26.

[5] M. Beitelschmidt, Z. Wang, Ingenieurkoffer für Experimentalpraktika@home, Lessons Learn. 1 (2021) 1–8. https://doi.org/10.25369/ll.v1i1/2.16.

[6] S. Odenbach, J. Morich, L. Selzer, Praktikum ohne Präsenz - geht das?, Lessons Learn. 1 (2021). https://doi.org/10.25369/ll.v1i1/2.6.

[7] A. Jurado-Navas, R. Munoz-Luna, Scrum Methodology in Higher Education: Innovation in Teaching, Learning and Assessment, Int. J. High. Educ. 6 (2017) 1. https://doi.org/10.5430/ijhe.v6n6p1.

[8] M. Persson, I. Kruzela, K. Allder, O. Johansson, P. Johansson, On the use of scrum in project driven higher education, Proc. …. (2011). http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.217.9885&rep=rep1&type=pdf.

[9] M. Muller-Amthor, G. Hagel, M. Gensheimer, F. Huber, Scrum higher education - The scrum master supports as solution-focused coach, IEEE Glob. Eng. Educ. Conf. EDUCON. 2020-April (2020) 948–952. https://doi.org/10.1109/EDUCON45650.2020.9125304.

[10] M. Cursio, D. Jahn, Leitfaden zur Formulierung kompetenzorientierter Lernziele auf Modulebene, https://www.med.fau.de/files/2015/09/31072014_leitfaeden_fbzhl_1_2013_lernziele.pdf, Erlangen, Nürnberg, 2013.

[11] Verbundes europäischer Lernwerkstätten (VeLW) e.V., Qualitätsmerkmale von Lernwerkstätten und Lernwerkstattarbeit, https://www.forschendes-lernen.net/files/eightytwenty/materialien/VeLW-Broschuere.pdf, Deutschland, 2009. http://www.forschendes-lernen.net/files/eightytwenty/materialien/VeLW-Broschuere.pdf.

[12] B. Kruppke, Digital Experiments in Higher Education—A "How to" and "How It Went" for an Interactive Experiment Lecture on Dental Materials, Educ. Sci. 11 (2021) 190. https://doi.org/10.3390/educsci11040190.

[13] Phyphox®, RWTH Aachen Univ. (n.d.). https://phyphox.org/.

[14] S. Staacks, S. Hütz, H. Heinke, C. Stampfer, Advanced tools for smartphone-based experiments: phyphox, Phys. Educ. 53 (2018) 045009. https://doi.org/10.1088/1361-6552/aac05e.