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Virtual Teaching of Linear Algebra with Complex Systems and Artificial Intelligence Case Studies

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Due to COVID-19, universities, higher education institutions, and schools all around the world had to shut down their on-site activities during the first semester of the academic year 2020 and teaching had to continue in an entirely virtual setting, either asynchronously or synchronously, or in a blended learning style. Several instructors were not fully prepared to teach virtually and a fast adaptation to the new and unusual circumstances was needed. While this unfamiliar situation has brought technical and especially educational hurdles, instructors are currently preparing for the second semester 2020 with a new awareness, taking into account lessons learnt from the previous semester. In this abstract, we outline our instructional concept for virtually teaching a one-semester linear algebra course in the BSc program Business Information Technology at FHNW in Switzerland. Students of this study program are likely to hold management positions working at the intersection between business and IT, where it is essential to conceptually understand mathematical methods, and apply these in dynamic business projects, often involving complex systems and artificial intelligence.

We propose an instructional design based on an overarching educational framework with two streams: *understanding by design* [1] and *virtual teaching best practices* [2, 3]. Understanding by design is an instructional planning approach focusing on achieving understanding based on backward design of the curriculum. There are three stages in backward design: identify desired result, determine acceptable evidence, and plan learning experience and instruction. Therefore, we formulated two learning objectives to identify the desired result: (1) students understand and are able to explain basic linear algebra concepts and to solve exercises as well as (2) to relate these basic linear algebra concepts to complex systems and artificial intelligence case studies. Acceptable evidence with respect to the first learning objective is assessed based on individual exercises that have to be handed in. Learning outputs are graded according to the criteria of understanding, correctness, creativity, and context, in combination with academic effort and collaboration between students. Acceptable evidence with respect to the second learning objective is assessed based on case study discussions. Quality and quantity of discussion inputs are the criteria for grading. Learning experience and instruction consist of five steps: *motivation*, *foundation and application*, *exercise*, *question and answer*, and *case study*. In our course we chose the five concepts *vectors and matrices*, *systems of linear equations*, *linear transformations*, *determinants*, and *eigenvalues and eigenvectors*. For each concept or topic considered in the course, all five steps are covered. The five steps are: (1) students watch

a ten-minute video created by the lecturer that introduces the topic motivating students to consider the ingenuity and relevance of the basic concepts as well as connecting these to important and especially intriguing and extraordinary applications and case studies. (2) Students read and study lecture notes created by the lecturer that describe definitions and notations of mathematical concepts and their applications. Lecture notes are structured in the same way for each of the basic concepts. (3) Students solve exercises provided in the lecture notes applying their knowledge about the basic concepts. Exercises are designed in such a way that students have to come up with their own concrete examples, guided by abstract descriptions. The scaffolding for solving these exercises is provided with examples given in the lecture notes. In addition, students help each other, if necessary, in a dedicated video conference. (4) Students ask questions to the lecturer in a one-hour question and answer video conference. (5) The lecturer asks questions to the students about a complex systems or artificial intelligence case study such as random matrices of various complex systems and Google's PageRank. Articles or book chapters are used as means of case studies and are provided in the appendix of the lecture notes.

The second stream of our educational framework is based on best practices shared by experienced practitioners involved in virtual teaching and evaluation. According to Purdy's [2] suggestions, we designed our virtual course according to the *three C's of course design*, which are *consistency*, *creativity*, and *community*. Consistency in this context means to design every virtual lecture according to the same structure, in order to avoid that students loose time in navigating virtual contents. Creativity in this context refers to multiple possibilities that technology can offer to students to share their understanding and learning of mathematical concepts. Using this multimodality as an assessment option, students can demonstrate cognitive and also affective ownership of the instructional content [4]. Creating a learning community in a virtual environment is not an easy task. By designing learning units through which students can engage with the learning content, the instructor, and fellow students, is a way to scaffold the learning experience. Our instructional design is also in agreement with the *six principles for planning virtual courses* as suggested by Schiefelbein [3]. These six principles are: *communication* in terms of frequency and regular check-ins, *consistency* as timely grading feedbacks, *organisation* as easy access to material, and clear directions and simple navigation, as well as *personalisation* since they want to be connected with the instructor by hearing and exchanging with him or her, *connection* with the material, and lastly *involvement* because students like to be an active part of the entire learning process.

The proposed instructional design will be used for the first time during the upcoming second semester 2020; however, we hope it is useful for other lecturers currently preparing their own virtual or blended courses.

References

[1] Grant Wiggins and Jay McTighe. *Understanding By Design*. Association for Supervision and Curriculum Development, Alexandria, 2005.

[2] Jill Purdy. How can the three C's of course design enhance students' online performance? *Magna Publications*, 2018.

[3] Jill Schiefelbein. What do students expect from online courses? *Magna Publications*, 2018.

[4] Mary Susan Love. Multimodality of learning through anchored instruction. *Journal of Adolescent & Adult Literacy*, 48(4):300–310, 2004.