



Adaptive Learning Technologies

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■ *Adaptive learning refers to technologies that dynamically adjust to the level or type of course content based on an individual's abilities or skill attainment, in ways that accelerate a learner's performance with both automated and instructor interventions. This column explores adaptive learning, its close relationship to artificial intelligence, and points to several results from artificial intelligence that have been used to build effective adaptive learning systems. The pairing of massive open online courses and adaptive learning has revealed new technical and pedagogical challenges that are currently being explored in various research projects.*

In his annual survey, the learning technology expert Donald Taylor asks more than 2,000 industry experts from different countries to estimate the most popular topics in workplace learning.¹ Since 2017, adaptive learning has been at the top of this ranking, finally being slightly overtaken by learning analytics in 2020. From the higher-education perspective, the EDUCAUSE Horizon Report 2020 included adaptive learning among the six emerging technologies and practices for higher education. This is confirmed by a recent survey³ where many chief academic officers consider adaptive learning as one of the most promising initiatives for improving the quality of student learning.

But, what's it all about? Adaptive learning refers to technologies that dynamically adjust to the level or type of course

content based on an individual's abilities or skill attainment, in ways that accelerate learners' performance with both automated and instructor interventions.⁴ It is closely related to artificial intelligence (AI) and is generally included in the area of AI in education. Its origin can be found back in the 1970s with the application of the first AI techniques, such as semantic networks and expert systems, to computer-based training systems to emulate aspects of human teaching. Nevertheless, the modern concept of adaptive learning was shaped early in the 2000s with the rise of online education and the growing attention of policymakers to the topic of personalized education, which led to the first specific funding initiatives for this theme.

Adaptive learning systems enable the development of individual learning programs and supports students' engagement so that their potential and success is maximized. They help in contexts with heterogeneous learners, that is, when learners have different cognitive backgrounds and learning preferences. They are also useful when learning needs are not standardized but each learner has specific requirements, such as in vocational training, on-the-job training, and so on. They support individualization of acquisition of skills through a diversification of teaching paths, and personalization as an achievement of cognitive excellence based on the specific intellectual potential of each learner.

From the methodological point of view, several results from AI have been used to build effective adaptive learning systems. Formal knowledge representation languages have been used to describe and organize the topics to be considered. Concepts from human-computer interaction, such as user modeling and adaptive hypermedia, have been adapted to the representation of students' knowledge state and learning preferences. AI planning and optimization algorithms have been used for curriculum sequence generation. Classification techniques based on machine learning have been applied to data gathering during the learning process, with the aim to predict training outcomes and preventing students from failing to achieve teaching objectives and leaving the course.

Recent research advances in AI-based adaptive learning, such as the ongoing European colMOOC project⁵, include *conversational agents* with natural language processing abilities, which have the ability to detect the student's cognitive state during the discussions in course chats and forums and intervene accordingly to guide, support, and animate students while engaging them in productive discussions on course topics. In addition, sentiment-analysis techniques have been used to detect student emotions and react with the appropriate affective feedback, while *recommender systems* have been used to suggest additional learning material based on previous knowledge or similarity with other students. Finally, machine learning and group decision-making techniques have been adopted for the automatic e-assessment of regular assignments, such as open-ended questions;

and complex assignments, such as dissertations, mathematical proofs, and computer programs.

In addition to research initiatives, there are companies, technology startups, and academic publishers that now offer adaptive learning technology resources. For example, CogBooks⁶ distributes an adaptive learning solution for training providers that can be used as stand-alone or integrated with third-party learning systems, such as Moodle or Blackboard. Smart Sparrow⁷ distributes a system with course-adaptation capabilities based on instructor-defined rules, and also supports emotion detection. Some long-established academic publishers are also entering this market. For example, the SmartBook Adaptive Learning⁸ solution distributed by McGraw-Hill Education leverages data collected during e-assessment sessions to adapt the learning experience based on student scores.

At this point, we can ask ourselves how much these technologies are really present today in the global panorama of education and training. Since 2016, the adoption of high-quality adaptive courseware has been strongly enhanced by a grant from the Bill and Melinda Gates Foundation, administered by the Association of Public and Land-grant Universities⁹ involving eight public US universities across several disciplines. There are also several self-funded pilot initiatives taking hold around the world; for example, in 2017, the National University in California launched the Precision Education Initiative¹⁰ to create a comprehensive educational environment integrating adaptive learning technologies. And in the same year, the Oregon State University collaborated with Smart Sparrow to build an adaptive online chemistry laboratory.¹¹ In 2018, the University of Central Florida made a strategic investment in the use of adaptive technologies to address students' academic success and improve completion rates.¹² And these are just a very few of the many recent initiatives.

However, while adaptive learning awareness in universities and colleges is higher than ever, and numerous institutions have piloted this technology, large-scale implementations are still very few. In the 2019 edition of the EDUCAUSE Horizon Report,¹³ it is argued that the biggest challenges for large-scale implementation lie in the investments of time, money, resources, and vision needed to implement and scale these courseware products. Optimal ways must also be found for integrating these technologies into existing learning processes. Apart from a few isolated initiatives, it currently appears that most institutions are waiting and observing, while early adopters share what they have learned.

Meanwhile, adaptive learning technologies are being asked to face new challenges coming from massive open online courses (MOOCs) that involve thousands of simultaneous participants, with some courses offered by Coursera and Udacity — just to mention some of the most popular providers — exceeding 100,000 registrants. Due to their scale, MOOCs introduce new technical and pedagogical



challenges for adaptive learning. Indeed, MOOCs are intended to serve an indefinite number of participants with a high heterogeneity of contexts, profiles, and starting points. Furthermore, due to the high number of students and the relatively small number of tutors, their involvement during the delivery phases must be limited to the most critical tasks.

What could be the result of matching MOOC and adaptive learning? At the moment, this direction, although promising, is still underdeveloped. Some research projects are beginning to explore this field. Let's wait and see — some interesting results will come out soon.

Notes

1. donalddhtaylor.co.uk/insight/the-ld-global-sentiment-survey-2020-first-thoughts/
2. <https://library.educause.edu/resources/2020/3/2020-educause-horizon-report-teaching-and-learning-edition>
3. www.acao.org/assets/caosurveyssummary.pdf
4. er.educause.edu/articles/2016/10/adaptive-learning-systems-surviving-the-storm
5. The European colMOOC project: colmooc.eu
6. www.cogbooks.com/
7. www.smartsparrow.com/

8. www.mheducation.com/highered/connect/smart-book-adaptive-learning.html
9. www.aplu.org/projects-and-initiatives/personalized-learning-consortium/plc-projects/plc-adaptive-courseware/program-overview.html
10. precision.nu.edu/index.html
11. <https://ecampus.oregonstate.edu/news/2017/online-science-lab-smart-sparrow/>
12. er.educause.edu/blogs/2018/7/vanguard-projects-expanding-teaching-and-learning-horizons
13. library.educause.edu/resources/2019/4/2019-horizon-report

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