

# OPENING UNIVERSITY EDUCATION TO THE WORLD AND IMPROVING EDUCATION: USING MOOC-BASED RESEARCH AS A TOOL FOR INNOVATION

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## Abstract

Online education can be used as a catalyst for gaining knowledge on learning and learning processes due to its generation of massive corpora of data on student behaviour. This knowledge can then be utilized to improve the quality of education. Since 2013 the Delft University of Technology (TU Delft) Massive Open Online Courses (MOOC) programme has created and run over forty MOOCs, gaining more than one million enrolled students in the process. As TU Delft's MOOC programme developed and expanded over time, an organisational structure was created in which educational processes and research activities were aligned and integrated. Through this integrated organisational structure, data is collected and analysed, which has resulted in a substantial number of evaluation reports, analyses, and academic papers. TU Delft has benefited from the insights from this combined output and has adapted to the findings both in online and on-campus course design. This way TU Delft's MOOC programme provides a valuable environment for innovating educational design experience and developing new educational delivery strategies that can also be used to improve on-campus education.

Keywords: Higher Education, Innovation, Learning Analytics, Massive Open Online Courses (MOOCs), Links between Education and Research.

## 1 INTRODUCTION

Online education can be used as a catalyst for gaining knowledge on learning and learning processes due to its generation of massive data corpora on student behaviour. These insights can then be utilized to improve the quality of education [1][2][3].

Since 2013 Delft University of Technology (TU Delft) has offered online courses for a global population of lifelong learners through its programme of Massive Open Online Courses (MOOCs). TU Delft's MOOC programme was created with three specific goals in mind: (i) to deliver high quality open & online education (O2E) to the world; (ii) to improve on-campus education; and (iii) to enable novel research opportunities [4][5]. Since its inception, TU Delft's MOOC programme has created and run over forty MOOCs, gaining well over one million enrolled students in the process [6].

As TU Delft's MOOC programme developed and expanded over time, an organisational structure was created in which educational processes and research activities were aligned and integrated. This organisational structure supports three research agendas: (i) course evaluation, which focuses on post-course analysis; (ii) research-driven innovation through short-cycled research projects; and (iii) long-term experimental research with a specific focus on big data and learning analytics.

By careful synchronization of these three research agendas with the educational processes, TU Delft has benefited from additional and otherwise unattainable insights and has adapted to these findings in both online and on-campus course design. This enables TU Delft's MOOC programme to provide a valuable environment for innovating educational design experience and developing new educational delivery strategies. In this paper we describe TU Delft's MOOC programme and the alignment and integration of supporting research processes. We also argue such a setup has benefits for the university and its educational processes.

## 2 TU DELFT'S MOOC PROGRAMME

TU Delft MOOCs cover a wide variety of topics, ranging from pre-university mathematics, to principles of solar energy, to quantum cryptography [5]. They are accessible to anyone with an internet connection, although some advanced courses benefit from a certain level of prior knowledge (often

attainable in other MOOCs). For a small additional fee those students who successfully complete and pass the course can get a validated certificate that verifies their achievement.

Through TU Delft's MOOC programme professors that wish to design and set up an online course are supported by a course team [5], which includes an e-learning developer, an instructional designer, and a number of student assistants. In addition, the programme provides access to marketing experts, multimedia experts that professionally facilitate video recordings, graphic designers, and many other specialists who can help in designing and developing high-quality online courses. For this, the programme makes use of a course design method based of the Carpe Diem Approach [7] and a research-based pedagogical model, called the Online Learning Experience [8][9][10].

TU Delft's MOOC programme has provided freely accessible education to many learners around the world. At the same time the programme has impacted campus education and research [5]. Developing their MOOCs has also provided professors with an opportunity to revise their campus courses, by using material from their MOOC or the entire MOOC itself in campus courses. MOOCs and the mass audience they attract have provided professors with excellent opportunities for research as well. Similarly, massive corpora of behavioural data are generated by MOOC learners; these data sets have provided TU Delft researchers with ample opportunities to gain actionable insights into large-scale learning phenomena, derived from fine-grained behavioural log traces [11].

### **3 THREE RESEARCH AGENDAS**

From the start of TU Delft's MOOC programme it has been recognized that MOOCs provide ample research opportunities for data-driven research [4][5]. For this reason, a research programme with MOOC-specific agendas was developed in parallel with the MOOC programme. Three research agendas arose, each characterised by different goals, priorities, and time horizons. In this section we describe these three agendas.

#### **3.1 Research agenda: Course evaluation**

With the goal of improving the learning process and experience of online students, TU Delft decided to systematically evaluate its MOOCs and to use evaluation outcomes to improve future online education resources [10]. For this purpose, students' opinions before and after a course are surveyed and analysed. The course evaluation research agenda is envisioned as a three-step quality control cycle: (i) sharing and communicating the evaluation results within TU Delft's MOOC programme; (ii) using the evaluation results to define "lessons learned" for online course design; and (iii) incorporating lessons learned into the course design and quality management processes in close cooperation with e-learning developers.

Raw course evaluation data, both qualitative and quantitative, is collected from several sources before, during, and after the course running. The MOOC platform's system logs provided quantitative behavioural data. To gauge students' opinions before and after a course, online surveys are deployed in the MOOCs: a pre-survey, which focuses on student expectations and previous experiences with online learning; a mid-survey, which focuses on student sentiments during the course; and a post-survey, which focuses on student engagement and experiences during the course. Before surveys are deployed, the questionnaires are checked with the course team and the e-learning developer.

Collected data is analysed and used to create two types of deliverables: course reports and cross-course reports. Course reports offer conclusions, lessons learned, and recommendations to be used by the course team and the professor to discuss the current course run and plans for the next iteration. Cross-course reports utilize data from multiple courses to conduct cross-course comparisons and observe various trends and developments. These can, in turn, be used to improve the overall online course development and MOOC programme itself, concurrently discussed with programme management.

#### **3.2 Research agenda: Short-cycled research projects**

The short-cycled research projects agenda was formed in order to support research that goes beyond a single course evaluation. The secondary objective was to provide (external) researchers with additional research opportunities with open and online education data, in order for TU Delft to learn from the results and improve the online learning experience accordingly. At the same time this allowed those external researchers to pursue their own academic endeavours, ensuring a mutually beneficial

arrangement. Within such a short-cycled project, researchers have the freedom to define their own research project, research questions, and approach within agreed-upon constraints (i.e. topic, time, budget), although preferred research themes include: didactics of online learning; learning content; teacher roles and styles; online group dynamics; and learner support.

A project is created by the researcher and TU Delft agreeing on a proposal that consists of the research question that will be answered, the methodology that will be used for this, the type of data that needs to be studied, an overview of resources the TU Delft should provide, and any associated costs / remuneration. Project deliverables are usually a research report and scientific papers.

### **3.3 Research agenda: Long-term experimental research**

The third research agenda focuses on fundamental long-term research into several aspects of open and online education. This research is carried out by TU Delft staff and aims to provide the MOOC programme with important insights in and practical experience with using learning analytics and learning analytics interventions in TU Delft MOOCs, albeit on a longer time horizon. TU Delft researchers are involved with research into MOOCs with a focus on learner modelling and learning analytics. The goal of this research agenda is to design and implement instructional interventions in MOOCs that support individualized learning at scale, built on actionable insights derived from fine-grained behavioural log traces [11]. The behavioural data is generated by learners taking TU Delft's MOOCs, and all interventions are deployed on the MOOC platform. The primary experimental method is randomized controlled trialling (i.e. A/B-testing). Learning analytics interventions are placed directly in a course and are deployed in the form of an A/B-test. Students in the test group can interact with the interventions, but also have the option not to use them. To analyse student learning processes, a variety of data processing and data exploration techniques are employed. Data is collected from two sources: (i) students' opinions on the course and the interventions are collected through online surveys that students voluntarily take; (ii) user profile data and user activity data (i.e. forum data, video watching logs, quiz answer submissions) collected from server logs, and then processed to derive higher-level insights. This research theme has been running since 2015.

## **4 ORGANISATIONAL STRUCTURE TO SUPPORT RESEARCH**

As TU Delft's MOOC programme developed and expanded over time, an organisational structure was created in which educational processes and research activities were aligned and integrated. This organisational structure supports the three research agendas. In 2015, efforts were made to more strongly align MOOC production and TU Delft research on open and online education. The purpose of this was twofold: (i) to better facilitate TU Delft researchers in their work, and (ii) to more quickly feed research findings into the course design process. For this purpose, a new evaluation process was constructed, including a structured approach, newly developed surveys, and a format for course evaluation reports. A data analyst and a student-assistant were hired to support the process. In addition, a research coordinator was assigned to keep track of all ongoing research in online courses.

The most important step in aligning and integrating educational processes and research activities was formalising the course design and quality control cycle. This was dubbed the 'TU Delft Online Learning Education Quality Cycle' (see Figure 1).

In this cycle, course development and research activities go hand in hand, and each phase of the course's life (Development, Run, Evaluation) is paired with and supported by specific research tools, methods, and deliverables.

### **4.1 Course development**

During the course development phase, course teams make use of previous findings from course evaluations and cross-course analyses in the building and testing stages. Of particular value are evaluation reports of the course's previous runs. Course teams discuss these with the course professor to check which adaptations to the next run are appropriate.

At the same time, the course team's insights are collected to contribute to further development of the Online Learning Experience model. And as a service, the professor is consulted by the research coordinator about the need for specific survey questions that are offered as part of the overall quality control surveys.

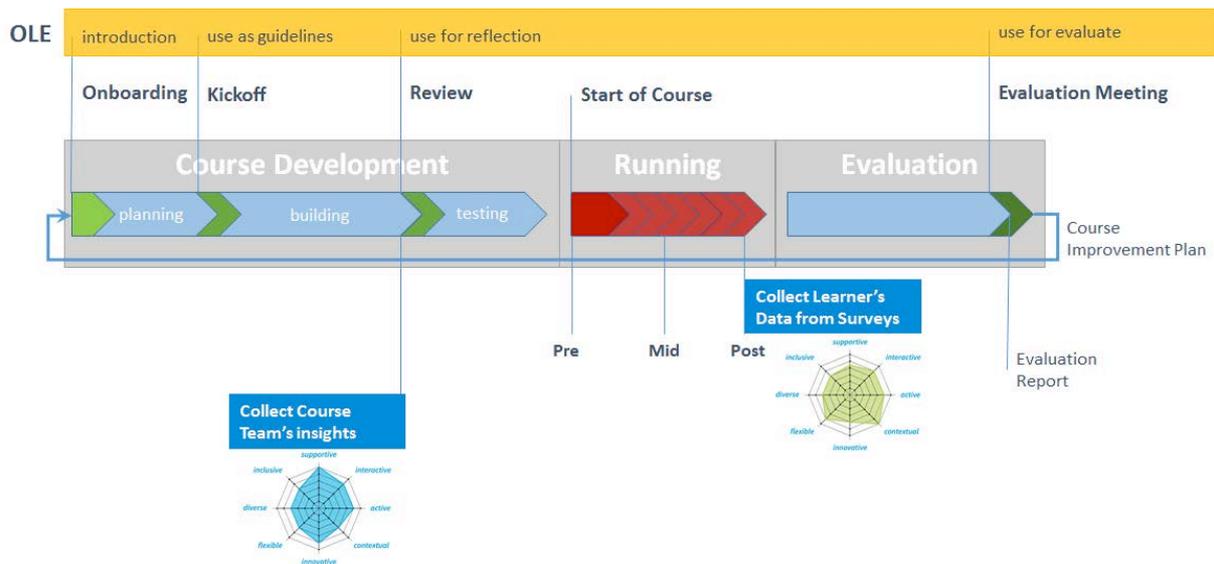


Fig. 1: TU Delft Online Learning Education Quality Cycle [5][9].

There are clear rules for deploying learning analytics interventions or other scientific research in a MOOC: (i) only reruns can be used for this purpose as to not interfere with new, first-run courses, and (ii) a good student learning experience is the most important aspect of a course, meaning experiments cannot jeopardize a positive, rich learning experience. If there are plans by other researchers to deploy an experiment in a specific MOOC, the professor is formally asked for permission. In the first stage, the product manager MOOCs and the research coordinator decide if experiments can potentially be deployed, and the professor is then formally asked for permission in the second stage.

## 4.2 Course run

At the start of the course run, the three surveys (pre-, mid-, and post-) are deployed at specific intervals in the course by a student assistant; this way they are part of the natural course flow. The purpose of the survey is explained to the MOOC students, and they are kindly asked to participate. It is specifically made clear that they can choose to opt-out, as participation is voluntary.

The tools for data collection (online survey system, web servers, the MOOC system itself) automatically collect data in such a way that they do not distract the professor, course team, or students. Anonymous survey results are sent to the course team during the course run to allow for on-the-spot adaptations if necessary. When students do have questions about surveys or research experiments, the questions are forwarded to the research team and promptly addressed.

## 4.3 Post-course evaluation

Privacy and research ethics are integral to research quality control. System data is collected in accordance with the MOOC platform's privacy policy, and online surveys start with an informed consent form. Data is securely accessible to specific researchers that are part of the MOOC research programme. All data is anonymized, either manually during processing and analysis or automatically through the use of the online survey platform. Any publications only use completely anonymous data.

Once the course has finished, both system data and survey data are automatically transferred to a secure drive the data analyst has access to. Specific research data is shared with those researchers who need it (e.g. for the Online Learning Experience model). A few weeks after the course has ended, the data analyst creates one or more evaluation reports, depending on the situation, and these reports are shared with the course team and responsible professor to be used for evaluation sessions and future course development processes. Through this process the TU Delft Online Learning Education Quality Cycle continuously improves course design and development.

## 5 USING MOOC-BASED RESEARCH AS A TOOL FOR INNOVATION

Through the integrated organisational structure, data is simultaneously collected for all three research agendas. Analysing this data has resulted in dozens of course evaluation reports, business and

marketing analyses, cross-course analyses, internal reports on student learning behaviour, and a substantial number of peer-reviewed academic papers. This output has been useful for each of the three individual research tracks described above, and combining the results has provided TU Delft with additional insights only attainable by careful synchronization. TU Delft has benefited from these insights and has adapted to the findings both in online and on-campus course design. TU Delft's MOOC programme provides a valuable environment for innovating educational design experience and developing new educational delivery strategies that can also be used to improve on-campus education.

## **5.1 Research agenda: Course evaluation results**

Since 2014 well over 100.000 responses to the course evaluation surveys were received and over 80 evaluation reports have been written. These consisted of 50+ course evaluations, 20+ cross-course reports (which compare MOOCs with other courses), in addition to a number of business reports. Course evaluation reports are used in evaluation meetings and during the production phase of the course's next iteration. Course instructors very much appreciate the reports and consider them valuable for future course (re)designs.

Cross-evaluating all MOOCs by using both student survey responses and system log data yielded important insights into the general perception students have of MOOCs, which course elements (e.g. videos, quizzes) they consider most important, how they felt course difficulty was handled, and how they assessed the overall course quality. In addition, insights were gained regarding the characteristics of students who repeat courses, how previous experience with online courses plays a role in course participation, and which barriers of entry influence a student's decision to enrol in an online course.

For example, cross-course comparison results have shown that students in all courses have the same preferences about course activities. Namely, course materials to view or listen to are always the most desirable. This suggests that students want, and possibly expect, a course that heavily relies on video materials, and subsequently highlights the importance of managing students' expectations, if, for example, a design would differ from these expectations.

Furthermore, we were able to gain insights into both student and teacher interactivity. In both cases there are multiple dimensions of interactivity that do not necessarily go hand in hand. Forums, for example, can be highly interactive on the surface, but deeper analysis can yield alternate findings (e.g., a large quantity of comments does not necessarily indicate true social engagement and interactivity). This means that forum assignments, such as asking students to post their opinions on a subject matter, should be designed with this in mind: simply asking students to post something might increase only a shallow level of engagement with the material/peers rather than a meaningful, deep interaction.

These and other observations were disseminated through workshops with the TU Delft Extension School's e-learning developers and resulted in improvements being made to the course design process. Business reports were discussed with the business development team. The results from the course evaluation therefore informed decisions on several levels and of several stakeholders, from e-learning developers, lecturers and course teams, to programme management---from course-level insights used to improve a particular course, to generalized cross-course insights used as guidelines for future course development.

## **5.2 Research agenda: Short-cycled research project results**

An open call for external researchers was sent out with the purpose of creating short-cycled research projects on quality and efficacy of open and online education. This open call for external researchers resulted in a number of applications. In 2015 a first research project was successfully launched as a result of this call. The goal of this project was to understand the actors and interaction processes in MOOC forums that together constitute social learning activities [12]. The project does this by providing a synthesis of focused research results from four MOOCs which are analysed using social network analysis and content analysis methods. The result of the project is a set of recommendations for the facilitation of MOOC forum discussions [13].

### **5.3 Research agenda: Long-term experimental research results**

The research, analyses, and experiments done by TU Delft researchers provide its MOOC programme with important insights in and practical experience with using learning analytics and learning analytics interventions in TU Delft courses. TU Delft researchers have already published more than 10 papers on MOOC research and have presented at international conferences.

The MOOC research team, housed in the department of computer science, has two primary lines of inquiry for their work on large-scale learning analytics. The first is that of exploring the manner by which the design of the online learning environment affects learner success and engagement. The second is concerned with modelling learner behaviour by looking beyond the MOOC platform.

The research team is taking a two-pronged approach with respect to its research on the design of the online learning environment. The first is a learner-centric approach that serves to gain a more complete picture of learners' natural behaviour in the course. To do so, they evaluated the extent to which learners adhere to (or deviate from) the "designed" learning path [11]. They then compared this designed learning path, or the course of learning activities in the order the course designers and instructor created, versus the "executed" learning path, or the sequence of events that the learner actually followed. Findings show that learners with higher adherence to the designed learning path are more likely to pass the course [11].

The next approach to researching the design of learning environments is that of experimentation; the extent to which certain manipulations to the interface and design can support student achievement is evaluated. One experiment tested the effectiveness of inserting support mechanisms for improving learners' study skills [14]. Another design intervention provided learners with a personalized feedback mechanism, a "Learning Tracker," which provided a personalized comparison between the learners' own self-regulatory behaviour versus that of a previously successful student in the course [15]. The Learning Tracker was found to increase completion rates among all student groups who received it [15].

By looking beyond the MOOC platform, the research team is able to gain novel insights about the learner which have yet to be explored in a learning context [16]. For example, one criterion for 'robust learning,' is 'learning transfer' [17]. Learning transfer is characterized by a learner applying what he or she learned in the learning environment to a novel context. Using the technique outlined in [16], TU Delft researchers were able to measure learning transfer in a computer science MOOC by evaluating the MOOC learners' behaviour in GitHub, a repository where computer programmers store and share their code [18]. They found a substantial number of learners who began coding during and continued to do so after the course, which had never done so before [18]. By continuing this line of research, TU Delft researchers can paint a clearer picture of how learners apply what they learn in MOOCs to their daily lives.

## **6 CONCLUSION**

TU Delft's organisational structure to support MOOC research provides a direct link between course development and empirical educational research. This way, the structure allows for an effective research cycle, which immediately feeds back into the course design process. In addition, due to the structure facilitating communication between researchers and course teams, all stakeholders in the MOOC programme are informed about research activities, leading to more mutual understanding and faster knowledge transfer. TU Delft's MOOC programme also proves to be a valuable environment for testing and experimenting with learning analytics interventions (such as learning activity trackers), and collecting learner behaviour data.

## **7 FUTURE PLANS**

A database containing all student behavioural and survey data is currently being set up to allow for broader, more in-depth analyses of learner behaviours. Future plans build on the current organisational structure and include (i) using the results from learning analytics interventions experiments to build a learning analytics 'suite' that can be deployed in all online courses; (ii) testing and validating TU Delft's proprietary Online Learning Experience pedagogical model for online course design; and (iii) using these experiences to transform and improve on-campus education. First steps in these matters are already under way with the acquisition of a new digital learning environment and its accompanying learning analytics suite for on-campus education. This way, the MOOC programme

serves TU Delft's strategic goals of both educating the world and improving the quality of its online and on-campus education.

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