WP 04-21

Implementing a class in Climate Change Economics: A case study how online resources facilitate interdisciplinarity in higher education

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The International School of Economics at Tbilisi State University (ISET) is supported by BP, the Government of Georgia, the Norwegian Ministry of Foreign Affairs, Higher Education Support Program of the Open Society Institute, the Swedish International Development Agency and the World Bank.

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31.05.2021

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Abstract

Tackling human-made Climate Change is among the main global challenges today and in the coming decades. Due to the interdisciplinary structure of the topic, the integration of Climate Change into the relevant higher education programs still lags behind. Online teaching resources such as Massive Open Online Courses (MOOCs) might contribute significantly to overcoming this deficiency.

In this paper, we describe the design of a class in “Climate Change Economics” and how we implemented it in a BA program at the International School of Economics at Tbilisi State University (ISET) in Tbilisi (Georgia). Our main focus is the integration of a MOOC on Climate Change and further online material as main teaching resources.

Our main conclusion is that the MOOC, supplemented with videos on special topics, is a suitable tool to facilitate an interdisciplinary introduction into Climate Change within an academic class in, e.g., Economics. The results of our evaluation show that online resources are highly motivational for students and encourage an efficient studying process.

Based on our experiences, we offer recommendations for further strengthening Climate Change as a topic in higher education. We provide suggestions on how online resources such as MOOCs might contribute to that aim.

1. Introduction

The authors introduced a class in “Climate Change Economics” as an elective class within the Economics BA program at the International School of Economics at Tbilisi State University, Tbilisi (Georgia). A so-called Massive Open Online Course (MOOC) served as the main teaching resource to establish a solid interdisciplinary basis for an economic analysis of the topic. We implemented the class in Spring and Fall semester 2020.

There is a growing interest to integrate the emerging discipline of Climate Change Economics in higher education programs. An economic perspective can make a significant contribution to analyzing the causes and consequences of anthropogenic Climate Change. Likewise, economic reasoning can contribute to an efficient design of solution strategies.

However, the interdisciplinary nature of the topic limits the integration of Climate Change into academic programs in Economics. A natural science-based understanding of Climate Change is an indispensable prerequisite for economic analysis. For instance, the transition to a carbon-neutral society happens on a timescale longer than one investment cycle and exceeds the horizon of most economic models. Integrating the natural science basis into a Climate Change Economics class is a challenging task. It requires establishing cooperation with lecturers from other faculties or finding lecturers with a specific interdisciplinary background. With conventional in-class teaching, this is often hard to organize.

Using an interdisciplinary massive open online course (MOOC) has various advantages in this regard. A MOOC is an online course that usually has a large number of participants and no admission restrictions. The production of MOOCs requires significant efforts, but once it is published, a potentially unlimited audience can benefit from it. MOOCs combine video lectures with interactive elements such as virtual discussion groups, and participants are free where and when to study. A main advantage of MOOCs is that they allow for an individual and interactive study process, for example by integrating interactive quizzes. MOOCs receive growing attention in academic education, besides their potential in informal education.[1, 2]

Another useful feature of a MOOC is that it can easily feature different lecturers and hence integrate the expertise from various academic disciplines and faculties. This makes MOOCs very promising to

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[1] Ebner M., Schön S., Braun C. (2020) More Than a MOOC—Seven Learning and Teaching Scenarios to Use MOOCs in Higher Education and Beyond. In: Yu S., Ally M., Tsinakos A. (eds) Emerging Technologies and Pedagogies in the Curriculum. Bridging Human and Machine: Future Education with Intelligence. Springer, Singapore. https://doi.org/10.1007/978-981-15-0618-5_5

[2] Kaplan, A. M., Haenlein, M. (2016): Higher education and the digital revolution: About MOOCs, SPOCs, social media, and the Cookie Monster. Business Horizons, 59, 4, 441-450, https://doi.org/10.1016/j.bushor.2016.03.008.

facilitate the teaching of interdisciplinary topics, such as Climate Change. First experiences with the application of MOOCs on Climate Change-related topics are promising.[3, 4, 5]

The main disadvantage of MOOCs is the limitation of social interaction. (In the current pandemic situation, however, any teaching process has to deal with this challenge.) Another disadvantage of MOOCs is that academic program regulations often require a university-specific examination process so that the MOOC alone cannot be used for assigning grades. To overcome these drawbacks, we followed a hybrid approach of combining self-organized, online-based learning and a conventional seminar setting (so-called blended learning).

This paper documents the designing and implementation process as well as the evaluation of the implementation. First, we introduce the underlying MOOC "Climate Change, Risks and Challenges" (Section 2.1), and we elaborate how we embedded the MOOC, supplemented by further online videos, into the overall structure of the semester (Section 2.2) and the weekly classes (Section 2.3). Section 3. depicts the implementation process in the Spring and Fall semesters of 2020.

Our evaluation methods are described in Section 4.1, and the results are presented in Section 4.2. Finally, we summarize our findings and conclusions (Section 5.), and we develop recommendations for a further strengthening of academic teaching about Climate Change and the potential of MOOCs within this process (Section 6.).

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[3] Senevirathne, M., Priyankara, H.A.C., Amaratunga, D., Haigh, R., Weerasinghe, N., Nawaratne, C. and Kaklauskas, A. (2021), A capacity needs assessment to integrate MOOC-based climate change education with the higher education institutions in Europe and developing countries in Asia: findings of the focused group survey in PCHEI under the BECK project, International Journal of Disaster Resilience in the Built Environment, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/IJDRBE-07-2020-0074

[4] Daniel Otto, D., Caeiro, S., Nicolau, P., Disterheft, A., Teixeira, A., Becker, S., Bollmann, A., Sander, K. (2019): Can MOOCs empower people to critically think about climate change? A learning outcome based comparison of two MOOCs, Journal of Cleaner Production, 222, 12-21, https://doi.org/10.1016/j.jclepro.2019.02.190.

[5] Coelho, J., Teixeira, A., Nicolau, P., Caeiro, S. & Rocio, V. (2015). iMOOC on Climate Change: Evaluation of a Massive Open Online Learning Pilot Experience. International Review of Research in Open and Distributed Learning, 16 (6), 152–173. https://doi.org/10.19173/irrodl.v16i6.2160

2. Class design

2.1. The MOOC ”Climate Change, Risks and Challenges“

We chose the MOOC named ”Climate Change, Risks and Challenges“[6] hosted on the digital learning platform “Mooin”[7]. To our knowledge, it is the only free-access MOOC in English language that comprises an introduction into climate dynamics, climate impacts, and solution strategies on a scientific level. The MOOC reflects the global scientific consensus of the recent Fifth IPCC Assessment Report.[8] The MOOC was published in 2017 by the scientific association Deutsches Klima-Konsortium (DKK) and the non-governmental organization WWF Germany, with financial support from the German Federal Foreign Office. [9] A guide for using the MOOC in an academic framework is available.[10]

The course content is organized into six chapters, each comprising seven to 12 lessons. Each lesson includes a main teaching resource, in most cases, it is a video of three to six minutes in length. The main resource is complemented with additional materials (videos, texts, links) and exercises. The total duration of the video material is approximately six hours. The videos are hosted on YouTube, so that familiar YouTube functions (such as changing the playback speed) are available while the videos are embedded into the course. Subtitles are also available to facilitate a better understanding.

Each video is designed as a short lecture focusing on a particular matter, including text-on-screen, graphics, and animations, and is lectured by a climate scientist who is a renowned expert in the specific field (see Figure 1). In total, about 20 climate scientists contribute to the MOOC, most of them affiliated with universities or academic research institutions in Germany. A few simple multiple-choice quizzes are embedded into each video and allow participants to receive immediate feedback on their individual learning process, though it is possible to skip them.

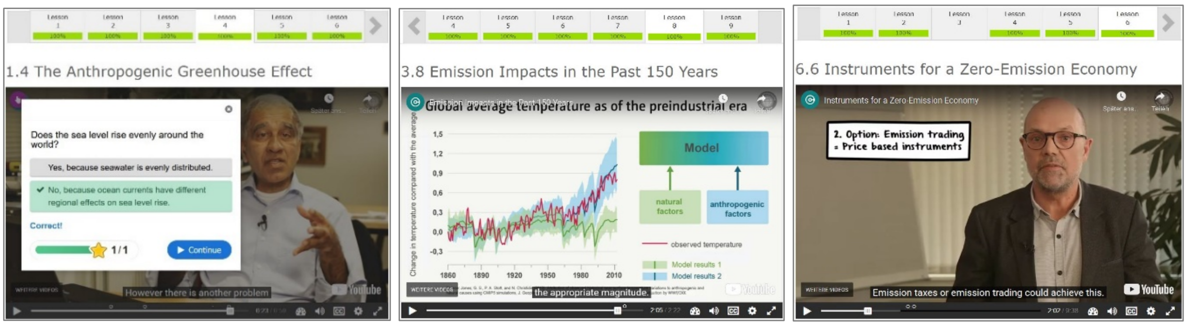

Figure 1: Screenshots from the MOOC. *left:* multiple-choice quizzes embedded into the videos allow participants an immediate feedback on their individual learning process. *middle:* animations facilitate understanding. *right:* “text on screen” highlights key terms and definitions.

[6] https://www.oncampus.de/weiterbildung/moocs/climate-change-risks-and-challenges?lang=en
[7] https://www.oncampus.de/mooin
[8] https://www.ipcc.ch/assessment-report/ar5/
[9] https://www.deutsches-klima-konsortium.de/en/education/climate-course-in-english.html
[10] https://www.deutsches-klima-konsortium.de/fileadmin/user_upload/pdfs/Publikationen_DKK/Manual_MOOC_ClimateCourse.pdf

2.2. Semester structure

The main learning objectives of the class in terms of scientific knowledge are an understanding of

- core principles of the climate system, the human impact on it, and interrelations of climate change and economy,
- solution options on the individual and the societal level, and
- relevant concepts of environmental economics and their application to climate change, such as, for example, 1. the concept of external effects and their internalization, 2. the effects of a tax on CO_2 emissions or a trading scheme for CO_2 emissions, 3. integrated assessment models of climate change and economics.

In terms of personal skills, the class allows students to improve their critical thinking skills in discussions, presentations, and writing, by

- Applying interdisciplinary scientific reasoning,
- Applying economic arguments in a controversial topic with large societal relevance, and
- Distinguishing between interest-oriented information and science-based knowledge.

The semester comprised 14 weeks of classes with a weekly class time of 90 minutes. We organized the semester along the following structure (see Table 1):[11] After an introductory class (week 1), we spent four classes on the scientific basics of climate change and societal and political conditions of climate protection (weeks 2 – 5). We assigned six classes (weeks 6 – 11) to specific topics of climate economics. In the next two classes, students gave presentations about their research projects on additional economic topics (e.g., empirical evidence from the EU Emission Trading System, week 12-13). The final class was a consultation session to prepare for the final exam (week 14).

We did not strictly follow the sequence of lessons in the MOOC, but changed the order of lessons in Chapters 5 and 6 to allow for more in-depth consideration of economic topics. Time restrictions also forced us to skip parts of Chapter 3. To complement the MOOC, we used video materials on particular economic topics (e.g., Coase theorem, Game theory description of climate policy) and on local examples (e.g., adaptation to Climate impacts in Georgia). While searching for additional material, we realized that it is not easy to find free-available videos on those topics that are in line with the compactness of the MOOC videos, as well as with their scientific and didactic quality.

The schedule comprised one extra meeting at first to play a social board game on climate change ("Keep Cool")[12, 13] and evaluate the results. We had to cancel this component in both the Spring and Fall semester 2020 due to pandemic-related restrictions.

Students earned 5 ECTS points for passing the class. Grading consisted of the following components: A written midterm exam (30%), a written final exam (40%), and presentations (30%). The midterm and final exams comprised multiple choice questions, open questions, and calculus tasks.

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[11] The first implementation in Spring semester 2020 used a slightly different structure. Here we present the revised structure for the implementation in Fall semester 2020.

[12] Meya, J. N., & Eisenack, K. (2018). Effectiveness of gaming for communicating and teaching climate change. Climatic change, 149(3-4), 319-333.

[13] Information on the game Keep Cool: http://www.climate-game.net/game-elements/?lang=en

Table 1: Overview of the semester schedule.

Week	Topic	Online material covered
1	Introduction	
2	Climate system and climate change in relation to economic drivers	MOOC Chapter 1 (all lessons)
3	Climate models and scenarios	MOOC Chapter 2 (all lessons), MOOC Chapter 3 (lessons 8-9)
4	Climate change impacts and adaptation measures	MOOC Chapter 4, MOOC Chapter 5 (lessons 4-5), video on adaptation in Georgia
5	Climate change as a societal and political challenge	MOOC Chapter 5 (lessons 1-3) MOOC Chapter 6 (1-4, 8-10)
6 – 11	Economic topics	MOOC Chapter 6 (lessons 5-7), 8 videos on Economic topics
12 – 13	Students‘ presentations	
14	Consultation in preparation for the final exam	

2.3. Weekly classes and the integration of online resources

MOOCs and other online sources allow for a self-organized, flexible study process. However, they make it harder to organize social interaction and discussion among students and instructors. This drawback of online learning motivated us to follow a hybrid teaching approach, where the instructor kept class time interactive and a real-time studying experience with the instructor delivering content (but not showing videos during class time).

Additionally, we gave students a homework assignment to prepare for each upcoming class in weeks 2 – 11. The homework assignments were to 1. work on specific lessons in the MOOC or additional video materials and 2. to prepare verbal answers to a set of “Key Questions”, to focus their attention on key learnings. In a few cases, we asked students to additionally read a short article or study a scientific diagram. We also encouraged students to work on the quizzes within the MOOC and to consider plentiful additional material within the MOOC, but on a voluntary basis.

While the focus of homework was on knowledge acquisition, the focus of the weekly class time was on highlighting key messages, clarifying questions, and discussing controversial aspects and personal opinions. To encourage interaction and students’ contributions, we asked volunteers to present their prepared answers to the key questions. An example of the integration of online-based homework and class-time is shown in Table 2. Further elements of weekly classes were the following: Lecturing additional content (e.g., climate impacts in Georgia), analyses of controversial texts (one of them being Greta Thunberg’s 2019 speech „How dare you“), Calculation tasks (e.g., equilibrium effects of a carbon tax in a fully competitive market), and analyses of scientific diagrams, e.g., figures in the IPCC Assessment Report.

The approach that students work on online materials prior to regular class time is classified as asynchronous online coursework integrated with traditional in-class instruction. The approach was inspired by positive results in another study.[14]

[14] D. Andone and V. Mihaescu, "Blending MOOCs into Higher Education Courses-A Case Study," 2018 Learning With MOOCS (LWMOOCS), Madrid, Spain, 2018, pp. 134-136, doi: 10.1109/LWMOOCS.2018.8534606.

Table 2: Structure overview of week 7 including the preceding homework assignment.

Homework for Week 7 (assigned at the end of class in week 6)	
Content	Method

• Work on Chapter 6 (Lesson 7) in the MOOC.
• Read the extract from the text “A Case of Posthumous Conscription“ by D. Friedman (2014).
• Prepare answers to the following Key Questions:
    • What is your opinion about the statement “Price-based/market-based instruments alone are not enough to solve the climate problem”?
    • In your opinion, would Milton Friedman have advocated a tax on Greenhouse Gas emissions?
• Solve the calculus tasks in the Study Guide.
	• online video
	• text reading
	• calculus
	• analysis of arguments, opinion-forming

Class time in Week 7	
Content	Method
Repetition of key terms and learnings from the previous class	Interactive quiz game (Kahoot platform)
Solutions for calculus task (homework): effects of a Pigouvian CO_2 tax in a competitive market	Interactive lecture
Climate change as a market imperfection: instruments and their evaluation • evaluation criteria; comparing regulatory to price-based instruments; reasons why price-based instruments alone may not enough for inducing the required long-term transformations (based on MOOC Chapter 6, Lesson 7) • Analytical comparison of the effects of uncertainty in a CO_2 tax and an emission trading scheme • Analysis of CO_2 price development in the EU Emission Trading System • Analysis of an exemplary global CO_2 abatement cost curve, barriers for the use of “low-hanging fruit” measures	Interactive lecture
Applying economic reasoning in political debates on CO_2 emission regulation, based on a controversial article	Discussion
• Summary: key learnings • Outlook on the topic of the next class • Homework assignment due in the next class • Organizational information, Q&A for the midterm exam	Interactive lecture

3. Implementing the class

We implemented the class in Spring semester 2020 and in Fall semester 2020 at the International School of Economics at Tbilisi State University (ISET), a public higher education institution in Tbilisi (Georgia). ISET offers a BA program and a MA program in Economics; both are fully taught in English.

The class was offered as an elective subject for students in the 2nd to 4th year of the BA program. The BA program comprises 240 credit points, among them 55 credit points from 11 elective classes (five credit points each). Besides the newly developed class in Climate Change Economics, the list of electives comprises two related topics: environmental economics and circular economics. Prerequisites for the Climate Change Economics class were the completion of the mandatory classes ”Principles of Microeconomics“ and ”Principles of Macroeconomics“. The syllabus reflected the class design as described in Section 2. ISET's academic board officially approved the syllabus prior to its first implementation.

The launch of the class in March 2020 coincided with the introduction of measures in response to the COVID-19 pandemic, in particular pausing all physical classes at higher education institutions in Georgia. Hence, we delivered the class in a remote teaching mode in both semesters. 45 students passed the class in the Spring semester, and 22 students passed it in the Fall semester.

We plan to offer the Climate Change Economics class also in future years and to widen the pool of potential instructors. The first author of this paper, who lectured the class in 2020, has an academic background in Climate Change research. But it is still an open question which conditions must be met so that other lecturers without this specific background can also teach the class. We intend to address this question in 2021.

4. Evaluation

4.1. Evaluation methods

Due to the pandemic-related remote teaching conditions, the interaction between lecturers and students was significantly reduced. Our opportunities for direct observations about the learning process and students' motivation were restricted hence. However, in-class discussions gave us the impression that most students gained a good understanding of the topics in the online materials. Apparently, the key questions in the homework assignments were useful to guide students.

We elaborated two standardized questionnaires to assess students' impressions about the MOOC-based learning process and to observe their acquisition of knowledge. Students filled out the first questionnaire after week 1. The focus was on prior experiences with online-based teaching resources and on a self-rating of knowledge about climate-related topics. The second questionnaire focused on the impressions regarding the MOOC and repeated the self-rating of knowledge. It was assigned after week 11. At this time, of the semester, the thematic input and the use of the MOOC were completed (see Table 1). We considered it useful not to postpone the second questionnaire to the last week of the semester to gain fresh impressions. 48 students answered the first questionnaire and 36 the second one. We present the results in Section 4.2.

Additionally, we performed standardized interviews with five students after the completion of the class. The results can be found in Section 4.3.

4.2. Results from the evaluation questionnaires

4.2.1 Motivation and expectations

The success of each learning process is framed by the learner's motivation and expectation. This holds particularly in a formal higher education setting, where students' striving for a degree with a good GPA often plays a dominant role.

In the first questionnaire, we asked students about their motivation for choosing the class and found a surprisingly high level of intrinsic motivation: Students rated the statement "I am interested in the topics of the class" with 4,21 out of 5 points on average and "I would like to save the world" with 4,35 out of 5 points. Also, the prospect of using an online-based teaching resource influenced students' choice for the class ("I am curious about the online course (MOOC)": 3,54). The pragmatic motivation to take the class primarily in fulfillment of the degree requirements played a far lower role ("I need the Credit Points / I need another elective class": 2,9).

Regarding their expectations, students gave high rankings to all answer options (see Figure 2). Mean values range from 4,04 ("learning about climate policy") up to 4,35 ("getting ideas what you can do in your private life"). One student added the following comment: *"Every year Georgia becomes [a] more significant part of global economy (right now it's not that big of a part but we will get there) and as I have decided to use my abilities in the future to help my country, it is interesting to me to know more about climate change economics as it will be crucial in the future of the world."*

It can be concluded that students had a strong intrinsic motivation for climate change at the beginning of the semester, related to the expectation to gain academic knowledge as well as practical skills to take action for climate protection in daily life.

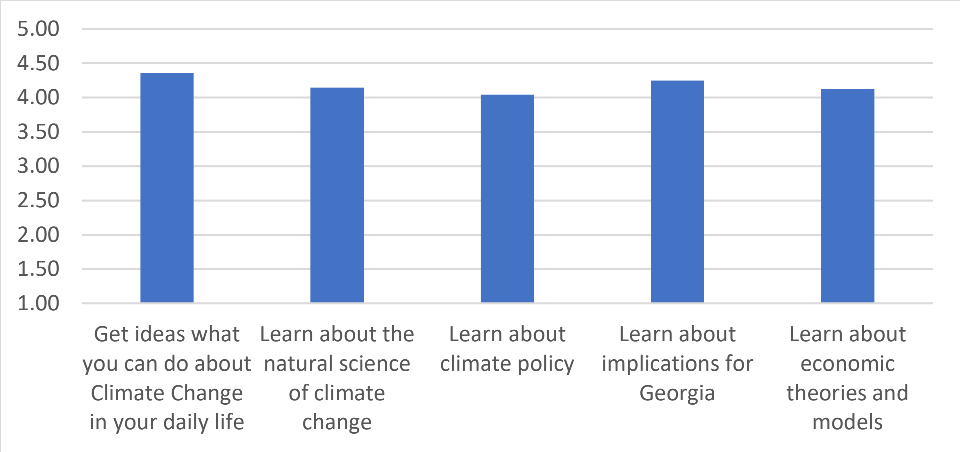

Figure 2: Students' expectations at the beginning of the class (mean values), assessed by questions "How important is it for you to …", on a scale from 1 (unimportant) to 5 (very important). Mean values.

4.2.2 Prior experiences with online learning

Students are nowadays very experienced with online-based resources in their daily life. It is hence not a surprise that most students had already often used the internet also for their studies (see Figure 3): On a scale from 1 ("never") to 5 ("very often"), 43 out of 48 students answer 3 or more (mean: 3,83). Many students also had already used online courses or online videos (mean: 3,29). The use of online courses or online videos as an official requirement of a class is not so abundant: 13 out of 48 students have never made such an experience before, the mean value is 2,08.

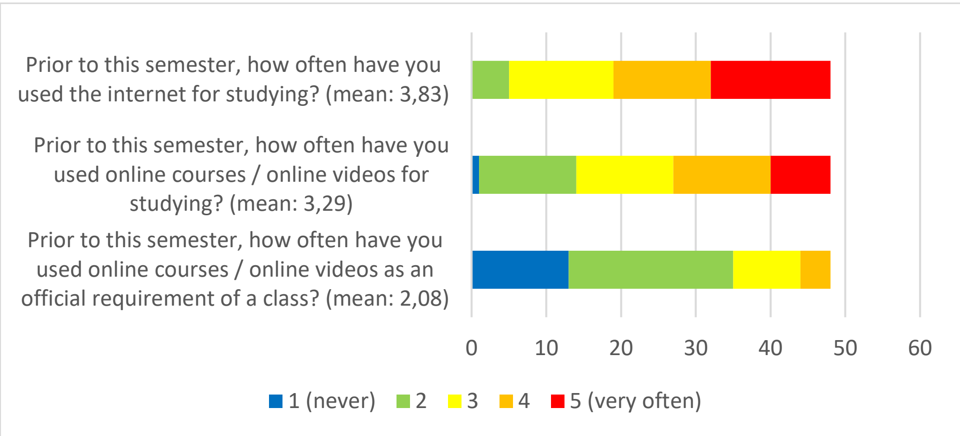

Figure 3: Results on prior experiences with online learning, on a scale from 1 (never) to 5 (very often).

4.2.3 Students' impressions on the MOOC

After completion of the MOOC, a large number of students rates the MOOC positively (see Figure 4): 21 out of 36 students gave it 5 points on a scale from 1 to 5, the mean value is 4,42. The teaching videos, as the main input providing element of the MOOC, also receive a positive feedback with a mean of 4,33, and no student rating them in the negative part of the scale (1 or 2 points).

As described earlier, only the videos in the MOOC were mandatory. The other features (interactive quizzes, discussion board, extra materials such as texts, internet links, further videos) were voluntary. We asked students how often they used these features. The result is a differentiated picture: The quizzes receive higher attention (mean 4,08) than the extra materials (mean 3,08). We explain this by the fact that the quizzes are embedded directly into the mandatory teaching videos. The comprehensive additional material in the MOOC did not attract most students' attention most students, presumably also because they received additional input in class anyway.

A broad majority of students rate the quizzes as useful or very useful (26 out of 36 answers are 4 or 5 points, mean 3,86). We conclude that students easily detect and then use a feature that is useful for their study process.

The teaching skills of the instructor clearly play a key role in any lecture situation, and this applies to teaching videos of a MOOC as well. In the majority of MOOCs, one expert acts as the instructor in the video material. The MOOC we used is special as it features a broader range of about 20 experts from various climate-related disciplines.

The performance of the experts in the videos receives high rankings (see Figure 5), in particular their professional competence (mean 4,42) and their comprehensible explanations (mean 4,03). All but one student gave a neutral (3 points) or positive (4 – 5 points) answer. The experts' motivational skills were also acknowledged (mean 3,75).

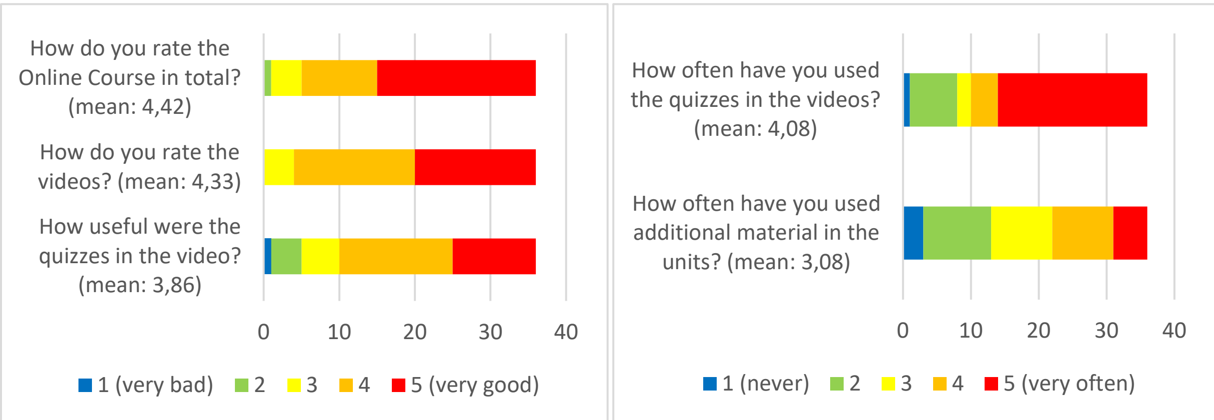

Figure 4: Results on impressions about the MOOC, on a scale from 1 (very bad/never) to 5 (very good/very often).

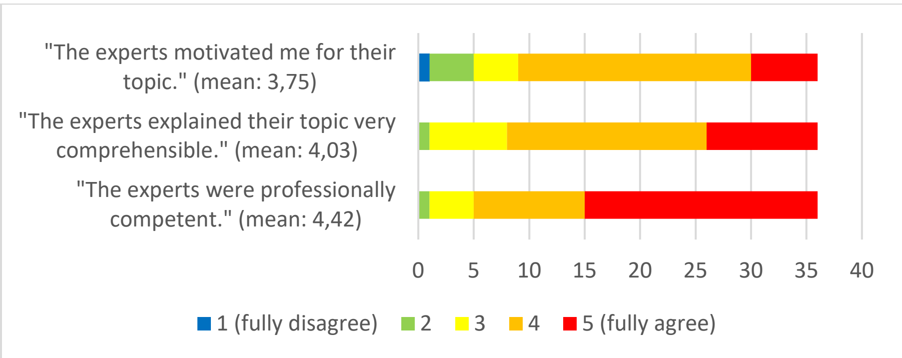

Figure 5: Results on impressions about the MOOC (cont.), on a scale from 1 (fully disagree) to 5 (fully agree).

4.2.4 Knowledge acquisition

We asked students for a self-estimate of their knowledge about specific climate-related topics, assuming that a self-estimate is a viable reference. If students give themselves a higher ranking in the second questionnaire, compared to the first one, we interpret this as knowledge acquisition.

First, we asked about “How do you rate your level of knowledge about Climate Change in general” (see Figure 6). Prior to taking the class, a broad majority of students had rather limited knowledge about the topic. 5 out of 48 students rank their knowledge with 4 points and no student with 5 points. The mean value is 2,71. After finishing the class, the mean value is 3,94, with 28 out of 36 students ranking their knowledge with 4 or 5 points.

We find a similar result for all assessed topics (see Figure 7). In the first questionnaire, mean values range from 3,35 (climate impacts on nature) to 2,0 (climate models). Topics with higher visibility or regular media coverage, such as the causes and impacts of climate change, receive higher values than the rather abstract climatologic topics, such as climate models and paleoclimate. In the second questionnaire, mean values range from 4,31 (causes of climate change) to 3,06 (climate change in the past). In particular, the increase in natural science related topics is remarkable (e.g., climate models: mean value 2,00 at the beginning, 3,53 at the end of the semester).

In total, the class initiated an efficient knowledge acquisition in a wide range of climate change-related topics.

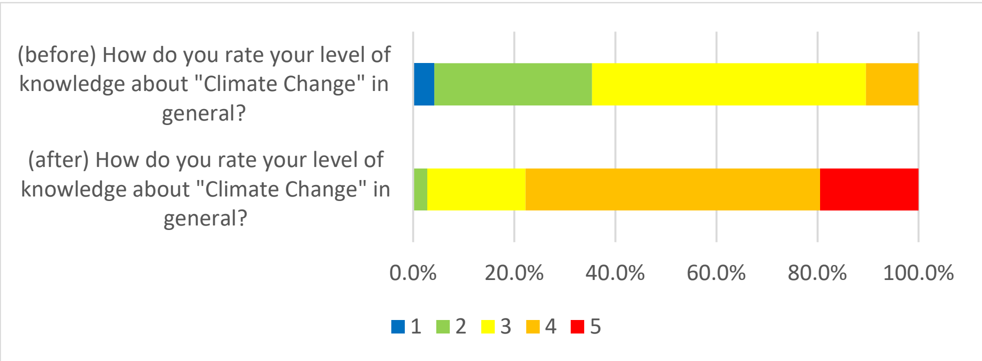

Figure 6: Students’ self-estimate of knowledge about climate change in general before and after taking the class on a scale from 1 (very low) to 5 (very high).

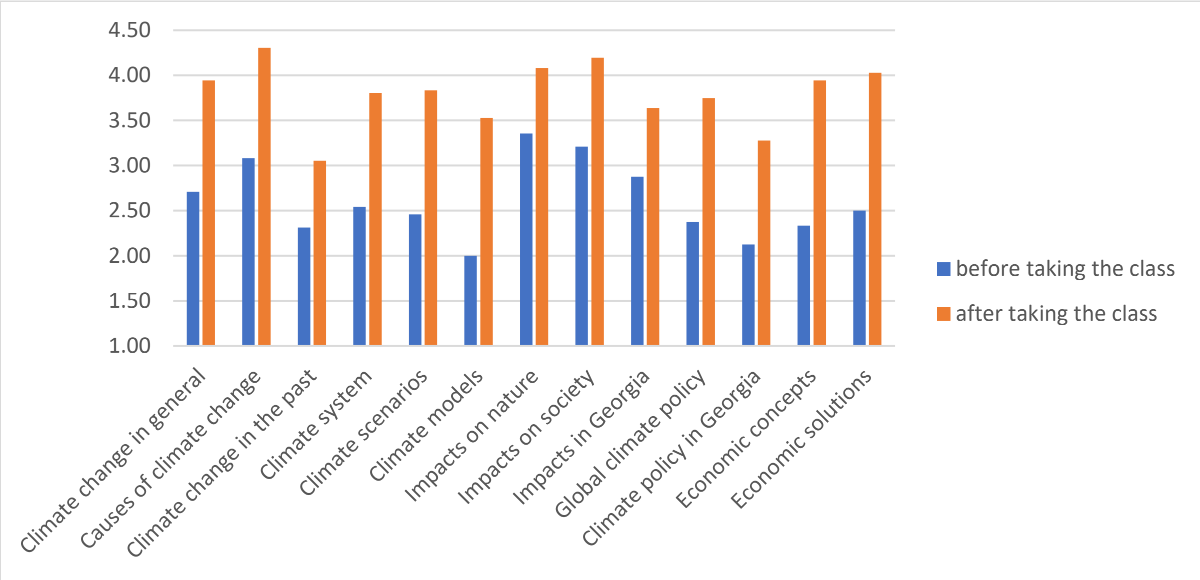

Figure 7: Students' self-estimate of knowledge about climate-related topics before and after taking the class on a scale from 1 (very low) to 5 (very high). Mean values.

4.2.5 Relevance for future studies and career

In the second questionnaire, we asked students how they evaluate the relevance of the topic for their future. The majority of students affirm the relevance for their future private life (25 out of 36 answers with 4 – 5 points, mean 3,83). This result is remarkable, since we covered the influences of personal lifestyle on the climate (e.g., consumption or dietary choices) only briefly. In connection with the results about motivation and expectations at the beginning of the class, we have the impression that students understand the relevance of climate change for their daily life and find answers to their questions.

Most students also have a professional interest in climate change, although many of them are rather doubtful about the relevance of the acquainted skills for their further studies and professional future (only 17 out of 36 answers with 4 – 5 points, mean 3,28).

4.3. Interview results

The purpose of the interviews with five students was to reflect and complement the results obtained from the questionnaires.

Our first set of questions was: is the Online Course/MOOC a good tool for learning, and why do you think so? Was the level appropriate as a resource in a BA class? The interviewed students rate the level of the MOOC as appropriate for a BA class. They particularly praise the videos. They highly prefer working on videos over reading texts or static presentation slides. In particular, students highlight that the embedded quizzes and the short duration of each video were useful to maintain focus. One student says she is generally a "fan of online courses", and she also takes courses in her free time. We conclude that the MOOC is a suitable teaching resource and relates well to the "everyday reality" of students. Offering short audiovisual media and interactive methods such as embedded quizzes connect the study process to students' ordinary media consumption.

In our second set of questions, we asked: We skipped some parts of the MOOC, and we changed the order of other parts: How was your impression about that? In the later parts of the semester, we used teaching videos from other sources for economic topics beyond the scope of the MOOC. How was your impression about that? – Students replied that the changed sequence did not confuse them, and adding videos from other sources was merely a "scenery change" and did not impede their learning process. Some students added it would have been nicer to stay on the same online platform, and that they missed the supportive effect of the embedded quizzes. We conclude that the MOOC can be used in a flexible way, not necessarily following the given sequence of lessons.

We then tackled the interdisciplinary approach of the class by asking: Was it clear for you why we spend significant time on the natural science of climate change and on climate policy? Students give positive answers, such as “of course, it is all interlinked“, and "to build the house you need the base - first we need knowledge about climate change and then we can interpret it with economics." We conclude that students share our understanding of the relevance of the natural science basics and political framework conditions for the topic.

According to the questionnaires, most class participants were very motivated to learn about climate change, but do not see much relevance for their future studies and career. We asked students in the interviews to comment on that. Students confirmed that they see few job opportunities related to climate change, since the field is not well developed in Georgia. One student mentioned though that he considers basic knowledge about climate economics as important for his planned business carrier.

Our final set of questions was, how important is climate change for Georgia, and why do you think so? Are people in Georgia aware of the importance, and aware of the solutions? Are the solutions we spoke about in class applicable for Georgia? In the opinion of the interviewed students, the awareness is still limited, because public attention rather focuses on current challenges such as the pandemic and inner politics. Most students express their doubts about the applicability of economic standard solutions in Georgia, such as a tax on CO_2 emissions. They point out the following barriers: low public awareness, low-income level, missing capacities in government/administration. Only a few students consider taxation on CO_2 as a realistic strategy.

Our conclusions from students’ feedback are twofold: First, there is an obvious gap between the importance of economic knowledge about climate change on one hand, and the unavailability of jobs on the other hand. This gap needs to be addressed in the future. Second, the real-world applicability of economic “standard textbook concepts” to countries in transition requires further research. This means in turn: The specific situation of countries in transition should receive more attention in education about climate change economics.

5. Summary and Conclusions

We designed a concept for a "Climate Change Economics" class in an Economics BA program. The free access MOOC "Climate Change, Risks and Challenges", supplemented with further videos on specific topics, served as our main teaching resource. Students prepared online lessons as their homework and answered key questions. The materials were then discussed and complemented in a conventional seminar setting. The main rationale for this hybrid approach was to integrate expertise from various disciplines, e.g., on climate dynamics, impacts, and politics, without losing opportunities for in-class exchange.

We implemented the class at the International School of Economics at Tbilisi State University, Tbilisi (Georgia), in Spring and Fall Semester 2020. A continuation from Fall Semester 2021 on is planned.

This paper contributes to the growing literature about the potentials of MOOCs as a teaching resource in higher education. Our particular focus was the potential of MOOCs to facilitate the integration of climate change (as an interdisciplinary topic with high societal relevance) into disciplinary degree-awarding programs.

Evaluation results. We evaluated the class based on questionnaires and interviews. The main results are as follows:

- Students have high intrinsic motivation for the topic. After completion of the class, most students affirm the relevance of their acquainted knowledge for their private life but not for their future career.
- Although students are very experienced in using online sources for studying, only a few of them worked with online material as a mandatory teaching resource before taking our class.
- A broad majority of students rates their experience with the MOOC positively. This also relates to the teaching of the experts lecturing the MOOC and the didactic element of interactive quizzes within the MOOC. Additional material available in the MOOC received only little attention. This is probably due to the hybrid learning setting that offered students room for discussion and extra input within the weekly class time.
- According to students' self-estimate, their understanding of a broad range of climate-related topics increased strongly. This holds particularly for abstract natural science-based topics such as climate models.

Conclusions. Our main conclusion from these results is the following: The MOOC, supplemented with further videos on special topics, is a suitable teaching resource to facilitate an interdisciplinary introduction into Climate Change within an academic class in, e.g., Economics. This didactic approach might be helpful also for lecturers who do not have an academic background in the natural science of Climate Change. We also conclude that online resources are highly motivational for students and encourage an efficient studying process.

There are limitations to the interpretation of our results. In future studies, further methods should complement the student self-estimate to gain more insight into their knowledge acquisition. Since our study relates to a specific academic program, the results cannot directly be transferred to further disciplines and other higher education institutions.

However, we are convinced that our approach to implementing a climate-related class in an Economics BA program serves as a promising case example, and we see large potential for similar efforts in other academic disciplines and institutions.

6. Recommendations

We would like to finalize this report by giving the following recommendations:

1. Higher education institutions in Georgia (and other countries in transition) should receive assistance for a sustainable implementation of climate change in their degree programs.

Our implementation concept can serve as an example of how to integrate the climate topic into higher education, but there are still barriers against widespread adoption. Future attention should hence be paid to overcome the barriers and to create transferable long-term implementation strategies. Higher education institutions need substantial support to solve this challenging task. The following ideas might contribute to the required capacity building:

- Assessing the potential for transdisciplinary cooperation among faculties and universities (for example: a climatologist and an economist from different universities cooperate to launch a climate change class that fits into both their academic programs).
- Initiating an exchange of experience among academic institutions in Georgia that have already launched or are interested in launching climate change-related classes in their programs, and defining best practices.
- Establishing international cooperation with academic institutions that have already larger experience in interdisciplinary teaching of climate change, e.g., in EU countries.

2. The potential of online teaching resources to facilitate the inclusion of climate change subjects in academic teaching should be explored far more.

In our experience, the MOOC "Climate Change, Risks and Challenges" makes an excellent foundation for teaching a basic understanding of climate change. However, to foster a widespread implementation of climate change in Economics and social science programs, it would be highly desirable to integrate further economic and political subtopics into the MOOC. Also, additional MOOC lessons on regional topics and applications would be beneficial to better cover the perspective of countries in transition.

With the upcoming release of the IPCC's sixth assessment report[15] and the new developments in international climate policy, initiated by the recent return of the USA into the global climate policy mechanism,[16] we also recommend an update of the MOOC to be produced. The general messages in the current MOOC version, based on the IPCC's Assessment Report 5, are not foreseen to change significantly. However, we believe that academic teaching in such a dynamic field should be based on the most recent scientific knowledge.

3. More attention should be paid to professional perspectives related to climate change in Georgia (and other countries in transition).

We regret that most students passing our class see only the limited relevance of their newly acquainted knowledge for their future studies and career. Providing them with specific information about climate change-related master programs and job opportunities might be beneficial.

Beyond that, students' impressions reveal a fundamental chicken-and-egg problem: On one hand, expert knowledge on climate change is currently largely "imported" to Georgia through international cooperation projects and foreign expert visits, due to a lack of domestic expertise. On the other hand, students in Georgia are highly motivated to achieve such expertise but are skeptical about

[15] https://www.ipcc.ch/assessment-report/ar6/
[16] https://unfccc.int/news/un-welcomes-us-announcement-to-rejoin-paris-agreement

career potentials in that field. Thus, there is clearly a mismatch between demand and supply for human resources with expertise on climate change issues in Georgia.

Establishing climate change-related academic research and education in Georgia – not only project-based but rather on a long-term scale – might be a first step to overcome the chicken-and-egg situation and contribute to a domestic availability of climate change-related, solution-oriented expert capacities in Georgia (and likewise for other countries in transition). The positive effects of such an approach will not emerge overnight, but they provide the foundation for a more successful and sustainable implementation of solutions to climate change in the long term locally and globally.

Michael Lüken appreciates valuable comments by Salome Japiashvili on a previous version of this paper.