From One-Size-Fits-All to Individualisation: Redefining MOOCs through Flexible Learning Paths

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ABSTRACT

Massive Open Online Courses (MOOCs) are a popular form of online education that often attracts a huge and heterogeneous group of learners with diverse interests and backgrounds. However, most MOOCs follow a one-size-fits-all approach, providing a fixed order of learning materials and expecting all learners to follow this recommended path. Thus, they neither motivate nor support their learners in adapting the courses to their individual preferences. In the work at hand, we tackle this issue by introducing and evaluating the concept of flexible learning paths in MOOCs. We, therefore, establish a network of dependencies between course content, omit intermediate deadlines, and thereby rethink the way learners interact with the course. By presenting learners with a non-linear course format, we encourage them to create their individual learning paths based on instructor-defined dependencies and their personal interests. Our evaluation of flexible learning paths within a programming MOOC shows that learners chose many different learning paths. Despite achieving similar results in individual tasks compared to learners using the traditional course structure, they engaged with less course content, resulting in a slight decrease in their overall performance. This may indicate a lack of self-regulatory learning skills, with learners struggling to organise their work without instructor-given deadlines. However, the flexible course format significantly increased the motivation of learners. By introducing and evaluating the concept of flexible learning paths in MOOCs, this work provides valuable insights into the individualisation of online education.

CCS CONCEPTS

• **Applied computing** → **E-learning**; *Learning management systems*; Interactive learning environments; *Distance learning*; • **Social and professional topics** → Computing education.

KEYWORDS

MOOC, Learning Path, Flexibility, Individualisation, Course Design, Self-Regulated Learning

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1 INTRODUCTION

Massive Open Online Courses (MOOCs) provide web-based learning materials for everyone. Learners can engage with the gradually released materials asynchronously and at their own pace as long as the desired materials are already unlocked. Thereby, learners establish an individual learning path, which is the sequence of activities they perform to reach their learning goal [35]. Most MOOCs resemble a lecture format with a fixed curriculum, incorporating videos and exercises. This form is often characterised as teacher-centric [29], meaning that the instructors create the learning materials and present them in a fixed order, defining the designed learning path [11]. While learners may deviate from this path, they mostly adhere to the given order [7, 11, 14]. However, there are also some instances of deviations where learners skip content or return to previous items. Yet, learners completing the course successfully deviate significantly less often from the designed learning path [14].

Due to the broad reach of MOOCs, learner demographics are very heterogeneous, encompassing differences in age, prior knowledge, motivation, and learning styles [19]. This diversity raises the question of why MOOCs adhere to a one-size-fits-all approach, where every learner is expected to follow the same content in the same order with the same schedule, rather than offering more flexibility regarding the time and content. A more flexible approach entails making all learning materials available from the course start, removing intermediate deadlines to accommodate more diverse learning schedules, and presenting course content in a way that avoids implicitly suggesting a single sequential order. MOOCs, unlike traditional classroom settings, have the significant advantage of providing a learning environment free from spatial and temporal constraints. This allows leveraging the capabilities of this digital setting to adapt the learning experience to individual preferences.

In this work, we present a non-linear course concept called flexible learning paths (FLP) that allows learners to choose their individual learning path. This approach contributes to tailoring MOOCs to the individual preferences and interests of learners. Further, it also provides learners with autonomy, potentially enhancing their motivation and performance [13]. While investigating flexible learning paths in MOOCs, we address the following research questions:

RQ1. How can a more flexible course structure be implemented into MOOCs?
RQ2. In which ways do learners interact with course materials using flexible learning paths?
RQ3. How do flexible learning paths affect learners' performance, motivation, satisfaction, and interaction?

The remaining parts of this paper are structured as follows: We first position our work in the context of existing literature in Section 2. Next, we present our concept of flexible learning paths in Section 3. In Section 4, we evaluate the concept within a programming MOOC and present possible limitations and further research ideas in Section 5. Lastly, we conclude our work in Section 6.

2 BACKGROUND AND RELATED WORK

Most MOOCs today follow a lecture-style format where instructors provide learning materials and learners progress through the course at their own pace. This instructional approach aligns with the behaviouristic principles of learning [16]. Hence, learners are required to independently determine when and how to engage with the content, which is called self-regulated learning [37]. The low completion rates of MOOCs, at around 13% [20], are often attributed to a lack of these self-regulatory skills [3], time and support [20], or motivation [25]. Semenova, for example, showed that the chance for successfully completing a MOOC is significantly higher if students are motivated, either intrinsically or externally [25].

Looking closer at how to motivate learners, the self-determination theory by Deci and Ryan asserts that learners feel intrinsically motivated when they perceive their actions as autonomously chosen, aligned with their values, and enhancing their competence [13, 24]. Offering choices in the learning process aligns with these principles and, therefore, has the potential to enhance learners' intrinsic motivation. A meta-analysis on the impact of choice on learners' intrinsic motivation and performance was conducted by Patall et al. [21]: Among the 91 analysed studies, 78 reported a positive correlation between the offering of choice and the motivation of learners, while 13 identified a negative correlation [21]. The findings further indicate that providing learners with choice can positively influence their task performance and perceived competence.

Looking at different research in the area of personalisation in MOOCs shows that learners prefer an experience tailored to their personal learning preferences [10]. This has been shown by Crosslin who analysed whether learners prefer an instructor-led course with a fixed linear path or a less structured course with a non-linear collection of tools. Therefore, they offered a course that allowed learners to choose between the two forms weekly. Their findings show no clear preference for either format, while also revealing that some learners switched regularly between them. They also found no common attributes that influence which format learners prefer. Overall, their findings show that learners have quite different learning preferences and desire a personalised experience.

In previous research, several approaches have been presented to adapt learning in MOOCs to the individual needs of learners. Sunar et al. provide a comprehensive overview of the available research on personalisation in MOOCs from 2011 to 2015 [29]. Their analysis shows a rapid growth in the interest in personalisation over the observed time span. The analysed studies propose different ideas, which include providing customised content, individualising feedback, recommending personalised learning scenarios, and creating individual learning paths. The individualisation was proposed to be based on the knowledge, goals, emotions, and learning styles of learners. Further, some analysed studies also present first implementations, such as an adaptive study planner for MOOCs [2], a text-mining-based approach to provide personalised feedback [27], and a learning cube that adapts learning contents [28].

Since 2015, further approaches have been presented. Rohloff et al. proposed the concept of personalised learning objectives in MOOCs [23]. These learning objectives allow learners to select a goal for participating in the course. The platform then adapts the learning path according to the selected goal by highlighting the necessary items without rearranging any content. Similar, Leach and Hadi enabled learners to choose parts of a course they are interested in. This was done by modularising the course and awarding badges for completed modules [17]. While still presenting the materials in a linear order, this approach encourages learners to choose the subset and order of modules more freely. However, Leach and Hadi have also shown that most learners still adhere to the presented order. Nevertheless, as outlined by Serth et al., those course modules might serve as a foundation for individualised learning paths [26]. In contrast to these approaches, our concept of flexible learning paths still expects learners to visit all course materials but instead encourages them to choose an individual order.

When it comes to creating learning path recommendations, different approaches have been proposed: Adorni and Koceva presented an algorithm that uses concept maps to create recommended learning paths based on the knowledge and goals of the learners [1]. Tahiri et al. suggested creating differentiated instructions for different user groups [30]. Further, Teixeira et al. proposed a framework that generates personalised learning sequences [31]. Their recommendations use the learners' profile, prior knowledge, and a list of module prerequisites to create individual paths for each learner. Bothe et al. provided learners with different micro learning videos to improve the use of MOOC content on mobile devices [8]. The presented order of suggestions is determined based on the dependencies between the videos, the learner's preferences, the videos already watched, and the feedback provided for previously watched videos. That way, individual sequences were created for each learner. A prototype of this approach was implemented and tested within the MOOC community. The results show only a low interest in the feature. Nevertheless, the study showed that learners have quite different topic preferences, resulting in many different presented orders of the watched videos. In contrast to the approaches mentioned above, which still create linear learning paths for each learner, we will focus on providing a more open format where learners can define their own learning paths. Since some topics build on each other and there may be didactic reasons for a partial sequence, we will highlight those dependencies for informed decisions.

3 CONCEPT

As highlighted before, enabling learners to influence their learning process through choice can significantly enhance their motivation. Additionally, tailoring the process to the needs and interests of learners can lead to substantial improvements in learning outcomes [15].

However, the majority of MOOC platforms present a fixed curriculum with a predetermined learning path. In light of this, our goal is to revise the structure of MOOCs and design a more flexible course concept. To ensure the best possible learning experience, we identified a set of requirements that should be satisfied:

- **Individualised Learning:** Learners can tailor the course to their preferences, interests, and existing knowledge [15].
- **Opportunities of Choice:** The new approach offers learners several decision points to enhance their motivation by allowing them to shape their own learning process [13].
- **Guidance:** The approach assists learners in making informed decisions regarding their learning paths [9].
- **Incorporation of Prerequisites:** The approach takes into account that learners are often expected to acquire some knowledge before progressing to advanced topics to ensure the creation of a meaningful learning path [5].
- **Progress Monitoring:** Learners are able to easily track their learning progress [36].
- **Consideration for Prior Knowledge:** The concept is able to adapt to different levels of prior knowledge, ensuring a tailored learning experience for everyone [4].

These requirements determine the core principles guiding our design, aiming to develop a new form of MOOCs that promotes individualised learning and provides choices while retaining essential elements of guidance and transparency.

3.1 Course Structure

We want learners to actively choose their individual learning path within a MOOC. Therefore, we grouped the course items related to the same topic in so-called learning units, which can be tackled in a single session. The items within a unit have a recommended order, but learners can still deviate from it. After completing a learning unit, learners can choose their next unit to work on.

Because MOOCs often convey complex topics, some learning units might require that learners gain some knowledge beforehand. Identifying the units to present as potential next choices should take these prerequisites into account. In order to achieve this, we introduce the concept of learning unit prerequisites, which serve as a guide, ensuring that learners follow a meaningful learning path. Each learning unit can have a list of other learning units as prerequisites. The network of prerequisites can be visualised as a directed graph (Figure 1), which should not contain any loops, as they would prevent learning units from fulfilling all their requirements.

To start a new learning unit, learners should ideally have fulfilled all required units. A required learning unit counts as fulfilled if a learner has completed at least half of its mandatory items. Videos and text pages are considered completed once the learner visited them, while gradable items like quizzes and exercises are considered completed if the learner has gained at least half of the available points. This approach ensures that learners actively engage with the items and gain at least a basic understanding of the conveyed content. With the concept of learning unit prerequisites, we can now determine how learning units are presented to the learner depending on their progress and the instructor-defined prerequisites to facilitate the generation of meaningful learning paths.

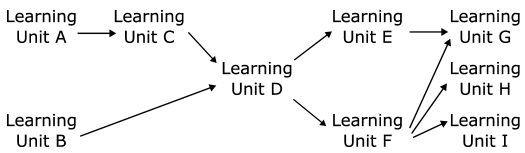


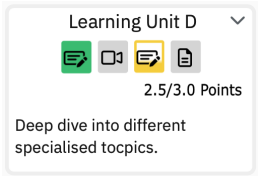
Figure 1: Example of a requirements graph with learning units as nodes and prerequisites as directed edges.

3.2 The Design of Flexible Learning Paths

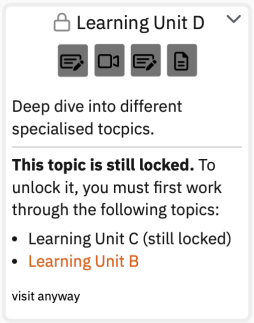
To present learners with their next options of choice, we designed a navigation page for learners that directly shows the previously introduced requirements graph. Each learning unit is presented as a node with a title, a short description, and an overview of the included items. Prerequisites are shown as connections between units. There are two types of learning units: unlocked units, whose requirements are all fulfilled, and locked ones with unfulfilled prerequisites. Unlocked learning units allow learners to navigate to the course items (Figure 2a). In addition, the learners' progress within the different items is indicated by the icon colour: non-visited items are displayed in light grey, visited but not completed items in yellow, and completed items in green. Further, the number of collected points is shown. Locked learning units, on the other hand, present the list of still-required prerequisites (Figure 2b). To cater to existing prior knowledge, a link at the bottom of the node allows learners to skip the prerequisites of a still-locked learning unit.

Some topics, like digressions or assessments, may have too many prerequisites or none at all, so they may not fit directly into the graph structure and are instead placed in a separate list. The navigation page further shows the percentage of visited items and earned points as progress bars. The described concept was implemented into the openHPI MOOC platform, which can be seen in Figure 3.

When a learner visits the navigation page, they see all learning units and their status. They can then choose a unit to work on and directly navigate to the corresponding item. When visiting an item, they see the content, along with a list of all items belonging to that unit. The linear ordering of the presented items provides a recommended order, although learners have the opportunity to



(a) Unlocked learning unit with progress information



(b) Locked learning unit with missing prerequisites

Figure 2: Visualisation of learning units depending on their status (unlocked or locked).

freely navigate between all items of the unit. To switch to another learning unit, learners have to revisit the navigation page.

With this new design of the navigation page for flexible learning paths, we have to also rethink the release of content and intermediate deadlines. Traditionally, new content is released periodically in MOOCs, often on a weekly basis. This practice facilitates uniform progress among learners, which enhances forum discussions and simplifies supervision. However, it also severely restricts the choice of learners within our new flexible course structure because only a limited number of learning units is accessible during the first weeks of the course. Therefore, we decided to offer learners a wider range of choices by providing access to all learning material from the beginning of the course. Further, courses often have intermediate deadlines to ensure continuous learner engagement. However, in the absence of a fixed learning path, expecting learners to complete specific topics by a set deadline may be an unrealistic approach. Therefore, we decided to extend all deadlines until the end of the course, giving learners the freedom to tackle topics in any order without intermediate deadlines.

4 EVALUATION

Next, we evaluated the impact of flexible learning paths compared to a regular four-week MOOC, and analysed learner satisfaction as well as interaction with the new format. In this section, we first provide an overview of the methodology in Section 4.1. Following this, we present the collected findings in Section 4.2 and discuss the potential implications of the results in Section 4.3.

4.1 Methodology

We evaluated the flexible learning paths within the Python programming MOOC 'Programmieren Lernen mit Python'[1] on openHPI. The course is designed for programming beginners aged between 12 and 18, but open to everyone. Given its introductory nature, the course mainly focuses on fundamental programming knowledge and builds towards the implementation of two small games. Each covered topic comprises a video to introduce the concept and syntax, an ungraded self-assessment quiz allowing learners to assess their understanding, and up to three programming exercises to solidify their understanding. Four graded assessments and two digressions complement the course.

To assess the impact of our new course structure, a randomised controlled trial with round-robin-like assignment was conducted. Since we expected a higher entropy of learning paths and learner progress during our experiment compared to regular courses (potentially affecting peer support in the course forum), we decided to apply a two-thirds split in favour of our experiment. Consequentially, 1,342 learners were assigned to the FLP group, which gained access to our implementation of flexible learning paths, while 674 learners participated in the course using the traditional linear course structure, forming the reference group (REF group). To prevent exchange between learners in different experiment groups, two almost identical courses covering the same content were created. The learners remained oblivious to the existence of the alternate course and were unable to alter their assigned course. Both courses ran concurrently over a 4-week period in autumn 2023. Adhering to the flexible learning path concept, the FLP course provided access to all content from course start, with all exercises and assessments due at course end. The resulting navigation page is shown in Figure 3. The REF course, on the other hand, released new content each week and had weekly assessment deadlines.

At course start, an optional survey captured the demographics, interests, and self-assessed prior knowledge from 1,249 participants (62.0%). At course end, 379 learners (18.8%) voluntarily shared their feedback on the course experience with us and evaluated the flexible course structure. During the course, we measured their intrinsic motivation using the "Kurzskala Intrinsischer Motivation (KIM)" questionnaire [34], a short German version of Deci and Ryan's Intrinsic Motivation Inventory [12]. In the questionnaire, learners evaluated their level of agreement with twelve pre-formulated statements on a 5-point Likert scale, which were combined to scores across four dimensions: (1) Interest and Enjoyment, (2) Perceived Competence, (3) Perceived Freedom of Choice, and (4) Pressure and

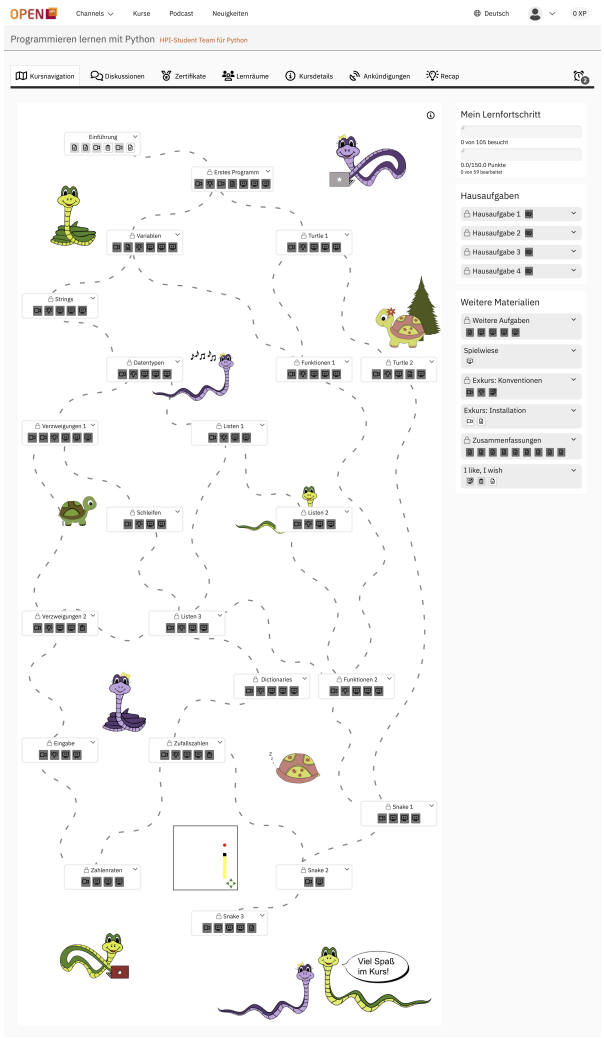


Figure 3: German navigation page used in the FLP course.

[1] https://open.hpi.de/courses/pythonjunior2023-2

Tension. Likewise, we asked learners whether they would recommend the course to their colleagues, friends, and family to determine the Net Promoter Score (NPS) as introduced by Reichheld [22]. By categorising learners as promoters, passives, and detractors, we calculated their satisfaction on a scale from -100 to +100.

In addition, information about the learners' progress and the performed events were captured. For our analysis, we only considered learners, who have logged in at least once since the course started.

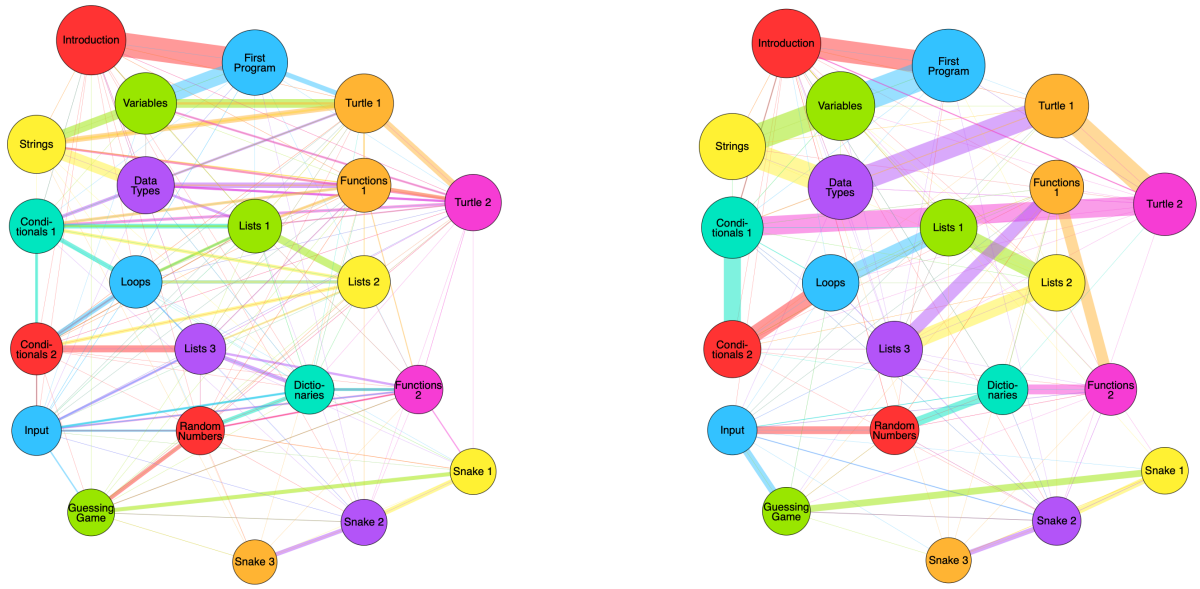
4.2 Results

In the following, we present the results of our study, in which 2,016 learners participated. Their age range spans from under 12 years to over 60 years, with 54.0% of learners being under the age of 20. 42.6% of learners joined the course for leisure activities or out of general interest, while 26.3% took part within a school lesson. 59.1% of the learners already had some programming experience before the course. Analysing both experimental groups for homogeneity using a Chi-Square Test revealed no significant differences regarding their age ($\chi^2(9) = 13.38, p = 0.15$), enrolment reason ($\chi^2(3) = 4.37, p = 0.22$), or prior experience ($\chi^2(2) = 0.68, p = 0.71$). Hence, the given distribution provides a solid foundation for our subsequent analysis.

4.2.1 Learner Perception. Overall, the flexible learning path concept was well received by learners, with 80.9% rating it as good or very good on a 5-point Likert scale and only 3.0% providing a negative rating. The new navigation page also received praise for being 'visually appealing', 'easy to understand', and 'motivating' and that it enhanced their learning experience. Learners particularly valued the ability to track their learning progress. In addition, they appreciated the clear presentation of requirements for each topic, easy navigation between course items, and the ability to skip prerequisites and explore topics freely. While our survey results indicate that 45.6% of respondents are open to the new navigation format, 48.2% of learners even expressed a clear preference for flexible learning paths and would like to see them in other courses.

However, 6.2% learners also criticised the navigation page for being confusing, difficult to understand, and too playful. They suggested providing a more detailed explanation of the navigation page and creating a clearer representation of the prerequisites. Criticism was also directed at the flexible approach, with some learners feeling that it complicated their workflow. They also expressed their frustration that they did not know how to decide what to do next, with 22.4% wishing for topic suggestions to work on next. Many learners were also used to the weekly structure of MOOCs and said that it was difficult for them to structure their progress, since the topics were not assigned to course weeks. However, the proportion of learners who raised criticism was significantly smaller than those who praised the new course format.

4.2.2 Chosen Learning Paths. The learners with flexible learning paths chose quite different paths through the course contents, as shown in the transition diagram in Figure 4a. The visualisation reveals that initially a majority of learners follows a shared path. Afterwards, the graph becomes more scattered as learners navigate through various learning units. Nevertheless, some of the paths attract more learners than others. Towards the more advanced



(a) FLP Group

(b) REF Group

Figure 4: Transition graphs for learning activity. Each node represents a learning unit positioned in accordance with its placement on the navigation page, its size is proportional to the share of learners who fulfilled this unit, and the colours are assigned randomly. The edges depict the transitions between the units, with the colour aligning to the colour of the starting node of the edge. The width reflects the share of learners who used the transition.

learning units, a reversion to a common path can be observed. However, the presence of edges connecting nearly every pair of nodes indicates the existence of numerous distinct routes chosen by the learners. For comparison, Figure 4b presents the transition graph for learners in the REF group, who were presented with the traditional linear course structure. A predominant path is clearly visible in this group, which aligns with the designed learning path provided through the order of content. However, there are also numerous instances where learners diverge from the predominant path. These deviations vary from skipping a single topic to more substantial leaps, both forward and backward in the course order. The comparison of the two graphs clearly shows that in the REF group, the majority adheres to the designed learning path, whereas learners in the FLP group chose many diverse paths.

Among the 243 learners in the FLP group who completed all learning units positioned in the graph structure, almost all opted for different learning paths. Only one learning path was chosen five times, which aligns with systematically solving all learning units from top to bottom and, within each row, from left to right. When asked about the factors influencing their decision-making process regarding their learning path, learners emphasised that their interests held the greatest influence. Following this, the position of the learning unit on the navigation page played a crucial role for many learners, as well as their prior knowledge. 76.8% of the learners who explored more than just the introductory learning unit always adhered to the presented prerequisites, only visiting unlocked units. The skipped learning units are distributed across the entire course spectrum, from introductory to advanced units.

4.2.3 Distribution of Engagement. Next, we investigate how the availability of the course content throughout the course runtime influenced the learners' distribution of engagement over the four-week duration of the course. One learner already completed all learning units by the second day of the course, and three more learners achieved this goal within the first week. However, most learners worked on the course content throughout the entire duration of the course. Figure 5 provides a detailed comparison of the behavioural patterns between the two groups by showing the average percentage of visited items, attempted programming exercises, and submitted homework assignments over time.

The upper two graphs show that the increase in the number of visited items and attempted programming exercises over time is similar between both groups and maintains a relatively steady pace throughout the entire course duration. Notably, just before the first intermediate deadline, there is a noticeable increase within the REF group, creating a slight gap between the two groups. The more noticeable difference can be seen in the third graph, which illustrates that throughout the entire course, the average number of submitted homework assessments in the REF group consistently surpasses that of the FLP group. Moreover, a distinct increase in numbers for the REF group can be observed leading up to each deadline. Conversely, in the FLP group lacking intermediate deadlines, this increment was only apparent towards the final deadline. Still, the numbers in the FLP group do not reach those of the REF group.

4.2.4 Distribution of Learning Units over Time. Figure 6 illustrates how many learners in both experiment groups visited the different learning units on a given day. Due to the periodical release of

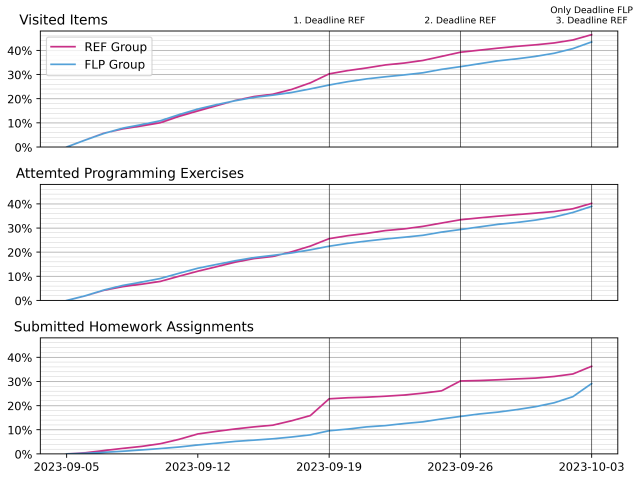


Figure 5: Comparison of the behaviour over time between the experimental groups, shown by the average percentage of visited items, attempted programming exercises, and submitted assessments per active learner. The vertical lines denote the intermediate deadlines in the REF course as well as the final deadline in both groups. A statistical analysis of the comparison is included in Table 1.

content in the REF course (Figure 6b), the activity is confined to the upper right part of the heatmap. Conversely, in the FLP group (Figure 6a), learners interacted with each learning unit almost every day throughout the four weeks of the course. Further, two accumulations are evident, where many learners worked on the same subset of learning units at the same time, one in the upper left part and one in the lower right part.

In the REF group, a fixed rhythm can be identified, with many learners working on the newly unlocked topics up until the deadline for the weekly assessments, creating four noticeable rectangles. Since learners were granted an extended deadline for the first week to accommodate latecomers, an overlap between the first two course weeks can be seen. After the deadlines, the engagement with the learning units noticeably decreases. Within each week, accumulations in the upper left and lower right part can be identified, similar to the trend observed in the FLP group over the whole course duration. Overall, the behaviour in the FLP group is much more distributed over the whole duration of the course. However, there are still multiple groupings where many learners worked simultaneously on the same topics.

4.2.5 Impact on Learners. Lastly, we want to investigate how the flexible learning paths impacted the learners.

Learners' Performance. To compare the performance of learners, we use some key learning metrics detailed in Table 1 for both groups. The learners in the FLP group exhibit a slightly lower level of engagement by visiting only 43.8% of the course items compared to 46.4% in the REF group. However, the conducted two-sided Mann-Whitney-U test ($U = 431,393, p = 0.09$) indicates that this difference is not statistically significant. Comparing the average number of achieved points shows that the learners in the

(a) FLP Group

(b) REF Group

Figure 6: Distribution of learner activity across learning units for each day. The colour indicates the number of learners who visited at least one item within that unit on a given day. In the REF group, content was released periodically, blocking access for learners until the content was unlocked.

FLP group obtained fewer points (31.5% vs. 34.5%). This difference is statistically significant with a weak effect ($r = 0.09$) according to Cohen. Further, learners gained a certificate, called Record of Achievement, for achieving at least 50% of the available points. Corresponding to the slightly lower number of points in the FLP group, the number of issued certificates in this group is also lower, with 29.4% of the learners in the FLP group receiving a certificate while 31.9% in the REF group achieve this award.

In order to understand how these differences came about, we next examine the individual components of the course. Learners in the FLP group completed slightly fewer programming exercises, but achieved almost the same points in these exercises and took the same amount of time solving them (14 minutes and 16 seconds in the REF group vs. 14 minutes in the FLP group). Overall, the behaviour within programming exercises shows no noticeable difference between the two groups. Continuing with the graded assessments, the learners in the FLP group, on average, completed only 29.3% of the assessments, while the learners in the REF group completed 36.5%. A Mann-Whitney-U test ($U = 393,568.5, p < 0.001$) indicates that this difference is significant with a weak effect (Cohen, $r = 0.17$). However, learners in the FLP group scored slightly higher in the assessments they took. And lastly, the performance within the voluntary self-assessment quizzes does not show any noticeable differences between the two groups, with learners solving roughly the same amount of quizzes and reaching the same points.

Learners' Motivation and Satisfaction. Next, we analyse the impact of offering choice on the motivation and satisfaction of learners by examining their self-assessed intrinsic motivation as well as their recommendation rate. Concerning their motivation, Figure 7 and Table 2 show the results obtained from the KIM questionnaire.

Table 1: Comparison of performance statistics.

Metric (Mean Values)	Test Group		Mann-Whitney-U		Cohen's r
	FLP	REF	U	p-value	
Visited Items	43.8%	46.4%	431, 393.0	0.090	
Total Points in Course	31.5%	34.5%	427, 680.5	0.045*	0.09
Exercises Completed	38.9%	40.1%	446, 923.5	0.606	
Points in Exercises	94.5%	94.6%	275, 411.5	0.816	
Assessments Completed	29.3%	36.5%	393, 568.5	< 0.001***	0.17
Points in Assessments	82.0%	80.7%	18, 750.0	0.160	
Self-Assessments Completed	44.4%	44.2%	474, 670.0	0.613	
Points in Self-Assessments	71.6%	71.0%	280, 104.0	0.396	

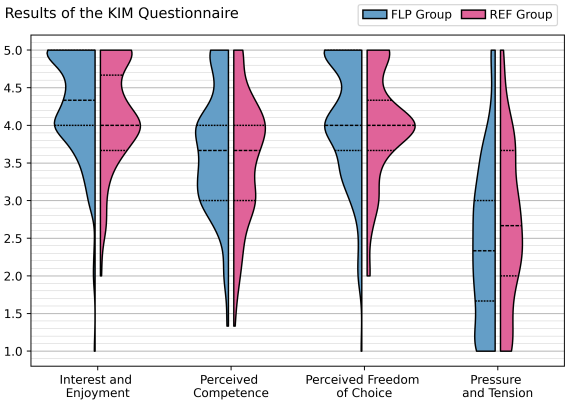


Figure 7: Distribution of the results of the KIM questionnaire along the four dimensions to compare the intrinsic motivation of learners between the experiment groups. A statistical analysis of the results is shown in Table 2.

Table 2: Statistical analysis of the KIM questionnaire.

Dimension (Mean Values)	Test Group		Mann-Whitney-U		Cohen's r
	FLP	REF	U	p-value	
Interest and Enjoyment	4.28	4.15	14, 552.0	0.03*	0.19
Perceived Competence	3.67	3.57	13, 835.0	0.21	
Perceived Freedom of Choice	4.08	4.00	13, 937.5	0.13	
Pressure and Tension	2.45	2.67	11, 238.5	0.02*	0.21

The results show that the Interest and Enjoyment in the FLP group with a mean of 4.28 out of 5 surpasses that in the reference group (mean: 4.15). A one-sided Mann-Whitney-U test ($U = 14,552, p = 0.03$) even reveals that the enjoyment is significantly higher within the FLP group, with an effect size by Cohen of 0.19 indicating a weak to medium effect. Additionally, the evaluation of the Pressure and Tension in the FLP group is, with a mean score of 2.45, significantly lower than in the reference group (mean: 2.67), as indicated by the one-sided Mann-Whitney-U test ($U = 11,238.5, p = 0.024$), with a weak to medium effect size ($r = 0.21$). Regarding the Perceived Competence, the evaluation in the FLP group is slightly higher than in the reference group (3.67 vs. 3.57), but not significantly. The same observation applies to the Perceived Freedom of Choice, where the evaluation in the FLP group (mean: 4.08) is only slightly higher than in the reference group (mean: 4.0), which is also not statistically significant.

Regarding learners' satisfaction, the results of the NPS confirm that the learners in the FLP group are much more satisfied and likely to recommend the course. Specifically, the course featuring flexible learning paths achieved a score of 40, while the traditional course format only reached a score of 22.

In summary, learners with the flexible course structure reported higher intrinsic motivation and enjoyment compared to learners with the linear structure, accompanied by a reduced sense of pressure. Moreover, the satisfaction of the FLP group, as measured by the NPS, is noticeable higher compared to the REF group, as scores above 50 are already considered excellent in learning contexts [33].

Learners' Interaction. Due to the flexible course structure, the engagement of learners in the FLP group is much more scattered throughout the duration of the course, as shown in Section 4.2.3. Since the exchange and mutual support between learners are important aspects of MOOCs, we want to investigate whether this effect has a negative influence on the interaction within the discussion forum. In the FLP group, 66.5% of the learners visited the forum at least once, while in the REF group, the number was noticeably higher at 78.7%. Further, only 11.5% of the learners in the FLP group posted in the forum, while in the REF group, the number was slightly higher at 13.8%. In addition, the median waiting time for an answer in the FLP course was with about 4 hours, noticeably higher than in the REF course with about 1 hour. This contrasts with the survey results, where 57.9% of the learners in the FLP group stated that they mostly got a helpful answer fast, while 13.2% stated that they experienced long waiting times. In the REF group, for comparison, only 50.0% stated that they mostly got an answer quickly, while 27.3% had the feeling of long waiting times, which are twice as many learners as in the FLP group.

4.3 Discussion

Through our study, we gained valuable insights into the individualisation of MOOCs, allowing us to discuss and summarise the impact of flexible learning paths in the following.

Perception of Flexible Learning Paths. The results of our experiment reveal a positive reception of our concept of flexible learning paths among learners, with a significant majority of learners indicating their interest in participating in other courses following the flexible structure again. In textual feedback, most learners expressed appreciation for our design of the navigation page, describing it as easy to understand and visually appealing, while others criticised it as confusing, too playful, and lacking necessary explanations. Despite the mainly positive feedback, we acknowledge that flexible learning paths might not suit every learner's learning style and preferences. Several learners, for example, expressed their desire for learning path recommendations. While highlighting one recommended option may help them structure their work, we also assume that this might diminish their freedom of choice. This can lead to many learners following the recommended path instead of choosing another path that better suits their interests. Determining the impact of these recommendations could, therefore, be an interesting subject for future research.

Chosen Learning Paths. Our analysis showed that learners with flexible learning paths chose quite different paths through the course. While we can recognise a general trend to start with simpler topics and to progress to more challenging ones, about 97% of all learners who completed the course chose unique paths. Therefore, our goal of creating individualised learning paths that are adapted to the learners' preferences seems fulfilled. Our analysis further shows that most learners adhered to our recommendations, avoiding locked topics until their prerequisites are met. Still, with 23.2%, there is also a noticeably large number of learners who skipped the prerequisites at least once. Possible explanations are that they already had some prior knowledge and decided to skip the known topics, or that they encountered difficulties and decided to continue somewhere else, or that they were just not interested in these learning units. According to survey responses, the decision-making process of learners is mainly influenced by their interests and prior knowledge. The provided layout of the navigation page also seems to guide learners in their decisions, as indicated by the five learners who independently chose the same path through the learning units, aligning with the positions of the units on the navigation page.

Impact on Performance. Examining the performance of learners within *individual course items* reveals no differences through flexible learning paths, suggesting that learners master the course content equally well regardless of the order chosen, whether given by the instructors or self-selected. However, a modest decrease in the *overall performance* can be observed, as learners engage with slightly less course content. Although the item visits in both groups showed a similar pattern at course start, their access patterns diverged as the first intermediate deadline approached: While the engagement in the REF group increased further, the engagement within the FLP group stayed the same. Despite the resulting difference being reduced towards course end, the level of engagement remained consistently lower. Further, a preference for last-minute

completions is evident in both groups, with many learners procrastinating their work: they start working once new content is unlocked, but then the engagement drops, only to increase again shortly before the deadline for the corresponding assessment. As learners using the traditional course structure were provided with four deadlines, this pattern repeated multiple times. Learners with the flexible course structure lacked these intermediate deadlines, which resulted in increased procrastination, and a heavier workload towards the course end. This also aligns with the findings by Luckner et al., who suggested that intermediate deadlines positively influence learners performance as they tend to procrastinate less [18]. Topolovec confirmed these findings in the context of MOOCs by demonstrating that self-paced MOOCs, lacking fixed deadlines, experience lower completion rates than instructor-paced courses [32]. This poorer performance could be due to a lack of the necessary self-regulatory skills, making it harder for learners to structure their work without externally provided deadlines. This has been confirmed by several learners who stated that they miss the weekly structure of the course and intermediate deadlines.

In conclusion, learners gain a comparable understanding of the content visited, but the overall course performance and thus the knowledge gain slightly decreases with the flexible course structure. We assume that one of the main reasons is the lack of intermediate deadlines, making it harder for learners to structure their work. In the current form, this can potentially impede the implementation of flexible learning paths for educators wishing to maximise learners' knowledge acquisition. Therefore, future research could seek to combine intermediate deadlines with flexible learning paths to compensate for the current disadvantages, i.e., by introducing dynamic assignments, automatically resembling content from finished units.

Impact on Motivation and Satisfaction. By providing learners with choices, we aimed to increase their motivation and satisfaction, in alignment with the self-determination theory [13]. According to the performed KIM questionnaire, learners with flexible learning paths rate their enjoyment significantly higher than learners in the reference group. Additionally, a statistically significant reduction in the perceived pressure can be observed. This could also be attributed to the absence of intermediate deadlines, which provides learners with more freedom to pace their learning process without regular fixed commitments. This supposition was even confirmed by some learners through their feedback. Contrary to our expectations, the perceived sense of autonomy and choice only marginally improved with the integration of flexible learning paths. We anticipated a more pronounced difference, given that learners in the reference group were expected to follow a fixed learning path while those in the test group encountered choices repeatedly. Likewise, the perceived competence showed similar results for both groups.

Overall, the results of the KIM questionnaire show a noticeable increase in the intrinsic motivation of learners through flexible learning paths. This is indicated by an increase in the primary scale, Interest and Enjoyment in conjunction with two other positive predictors, Perceived Competency and Freedom of Choice, as well as a decrease in the negative predictor Pressure and Tension. Additionally, learners with flexible learning paths are more satisfied with the course and much more likely to recommend it further, as indicated by a higher Net Promoter Score. Consequently, particularly self-paced courses without fixed deadlines are likely to benefit from the increased motivation introduced by flexible learning paths.

Impact on Interactions. One concern stemming from the dissolution of the fixed course structure, in particular from the removal of the weekly rhythm, is that the engagement is spread more across different learning units. This might, in turn, limit the interaction between learners in regular instructor-paced courses, as fewer learners simultaneously work on the same topics. Our analysis shows that learners with flexible learning paths continuously interact with the course materials, just like learners in the reference group. However, their engagement was much more spread over different learning units (Figure 6). Despite this, certain accumulations emerged where many learners simultaneously worked on the same units. Analysing the impact of this scattered engagement on learner interaction within the forum shows a decrease in activity. It reveals that 79% of all learners in the control course visited the forum at least once, whereas, in the experimental course, only 66% did so. This could be due to the fact that those learners did not have the need to ask questions since they already understood the content. Alternatively, the absence of intermediate deadlines and the periodic unlocking of new content might have influenced the activity in the forum negatively. As Boroujeni et al. showed, learner activity tends to surge after new content is released and shortly before deadlines [6], a dynamic missing with flexible learning paths. Furthermore, the learners in the flexible course often experience longer waiting times for responses. This delay could be attributed to the previously mentioned scattered activity across various units, which led to fewer learners being actively engaged with a given learning unit and therefore being available to provide help. Still, the learners rated their waiting time more positively, which might be due to the fact they had lower expectations, being aware that not everyone is working on the same learning units simultaneously. Looking at the possible implications of the reduced forum activity, we cannot rule out that this had a negative impact on the success of learners, as they had fewer resources from which they could gain help. Overall, while we observed a significant decline in the forum activity, we also know that fluctuations are normal and that the activity heavily depends on individual learners in the course [6].

5 LIMITATIONS AND FUTURE WORK

The examination of flexible learning paths in this study reveals some limitations that have to be considered when interpreting the results. Foremost, we evaluated the new concept only within a single course. Although we can certainly assume that our results are generalisable for introductory programming courses, other courses might yield different outcomes. In addition, we could not ensure the secrecy of the experiment, as some learners participated in the course together with friends and family. In cases of school classes, we occasionally switched group assignments to ensure that all pupils within the same class shared the same experiment group, allowing teachers to incorporate the course into their lessons. Due to the relatively small number of pupils, this did not have a significant influence on our experiments. We also conducted a second experiment evaluating the integration of pair programming into MOOCs. Although the groups for the two experiments were strictly separated and all assignments were performed randomly and independently, this fact

introduced additional variables, potentially impacting the study. Finally, a response bias may be present in the survey answers.

While this work provides many insights into how MOOCs can be enhanced through flexible learning paths, there are still many open ideas that can be addressed in the future. One idea is to develop a concept that caters effectively to learners who prefer a provided linear order of content, as well as those who favour a more flexible approach. Further, as our analysis showed, the missing intermediate deadlines might be a reason for the reduced performance of learners. To counteract this, different ideas to ensure steady progress should be evaluated. In addition, a feature to automatically identify learning units and dependencies could be added to allow for easy conversion of existing courses into a flexible structure. Moreover, the concept of flexible learning paths could be extended to facilitate the creation of course specialisations and offer alternatives. Then, the approach could be employed to offer structured content across course boundaries, visualising the dependencies between content in different courses and enabling materials to be found efficiently. Finally, we aim to generalise our findings and create a guide for educators to integrate flexible learning paths into their courses. As part of this effort, we plan to extract our current software prototype and make it available as a reusable component.

6 CONCLUSION

With this work, we introduce flexible learning paths to Massive Open Online Courses (MOOCs), a concept that provides learners the opportunity to choose their individual learning path, aligned with their needs and interests. This work presents the developed design and evaluates its perception and effectiveness. On the basis of our findings, we answer our posed research questions:

RQ1. How can a more flexible course structure be implemented into MOOCs?

Our goal was to develop a new course structure that empowers learners to autonomously choose their learning paths, while receiving support in their decision-making process. To reach this goal, we came up with the concept of flexible learning paths, which uses small groups of items and teacher-defined requirements between these groups to create a graph-like course structure. This structure allows learners to choose their individual learning path while ensuring that they always have the required knowledge to work on the course content. The graph structure is directly displayed to learners on a newly developed navigation page, which offers a clear overview of the groups and their dependencies. It also supports learners in their decision-making process, by displaying descriptions and progress information. Additionally, we decided to release all content at course start and eliminate intermediate deadlines to provide learners with more flexibility in their choices.

RQ2. In which ways do learners interact with course materials using flexible learning paths?

The results of our study reveal that learners utilising flexible learning paths interact with the course content in diverse ways, creating numerous individual learning paths. Their choices regarding the order of content are primarily influenced by their interests, prior knowledge, and the teacher-defined prerequisites. The broad range of selected learning paths and answers from the surveys indicate that the new concept achieved its intended purpose, tailoring the course to the individual needs and preferences of each learner. The majority of learners adhered to the presented requirements, only accessing content whose prerequisites have been fulfilled, while some learners deviated from the suggested path. Despite the release of all content at the beginning of the course, most learners distributed their efforts throughout the entire course duration. However, a pattern of learners procrastinating their work until the end of the course (and thus the only deadline) is evident.

RQ3. How do flexible learning paths affect learners' performance, motivation, satisfaction, and interaction?

Analysing the impact of flexible learning paths on the performance of learners reveals that they achieve similar results in individual tasks compared to learners provided with an instructor-designed learning path. However, examining the overall performance within the MOOC shows that they engage with less course content. This phenomenon is probably attributed to the absence of external pressure induced by intermediate deadlines, resulting in a slight decline in overall course outcomes. Further, learners with flexible learning paths interact less with others using the course forum, which could be attributed to the broader distribution of learner engagement across various learning units. However, this decrease does not negatively affect learners' perception of the interactions. Most learners are highly satisfied with the course and its flexible structure. Additionally, they are much more intrinsically motivated, feel less pressured, and are more inclined to recommend the course compared to learners with the traditional course structure. Based on these results, we conclude that the flexible format is particularly suitable for self-paced courses without fixed deadlines. Learners can take advantage of the benefits, such as higher motivation and engagement, while the drawbacks, such as reduced forum activity, have no effect on self-paced courses without active forum participation. Although there is a marginal decrease in performance and interaction due to flexible learning paths, the increased flexibility leads to higher motivation and satisfaction for most learners.

In summary, the newly introduced concept of flexible learning paths in MOOCs is well-received by learners, resulting in the creation of numerous individual learning paths. This diverse selection of paths chosen by learners suggests that the instructor-designed learning path, usually followed by most learners in traditional instructor-paced courses, might not be the optimal learning path for everyone. While some learners prefer a structured format with a recommended learning path and intermediate deadlines to help them organise their work, others desire more flexibility, aiming to tailor the courses to their individual needs. The results of this work suggest a growing interest among learners to incorporate more flexibility into MOOCs to allow adapting the courses to individual needs. Moreover, our evaluation reveals that the new course structure does not improve the performance of learners in MOOCs, but it significantly enhances their motivation and satisfaction by granting them autonomy in shaping their own learning journey. In particular, learners enrolled in self-paced courses are likely to take advantage of these benefits. Hence, the insights collected in this work, highlighting the positive reception of a more flexible course structure, provide a compelling foundation for future investigations into the individualisation of learning in MOOCs.

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