University of California, Berkeley

Improved Personalization in MOOCs to Enhance Student Learning

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Contents

Abstract

In this era of technology, online education platforms play a very important role in delivering quality education on diverse topics, overcoming the barriers of physical accessibility, high costs or personal disabilities. MOOCs provide an economical and flexible way to learn new skills and deliver quality educational experiences at scale. However, despite the high enrollment numbers, according to many studies, approximately 90 percent of people who sign up for most MOOCs fail to complete the course. The two main reasons for dropout as reported by users seem to be, misalignment between user's learning experience and his expectations which de-motivates them to continue with the course, and that users were too busy to continue. We believe that MOOCs can play a pivotal role in educating students in underdeveloped areas where it is difficult for large groups of individuals to learn through formal channels like schools and colleges. MOOCs can also be extremely useful in the developed countries as a medium to augment formal education. We have seen how technology can replace humans, eg. self driving cars taking over drivers, robots taking over salesmen etc. MOOCs can be useful in such dynamic environments for individuals interested in continuously learning new employable skills.

1 Background on MOOCs

A massive open online course is a model in which a learner can get access to world class university level content in an Internet based course. This form of learning has become increasingly popular as it is economically scalable and is available to a large number of audiences at a very nominal cost. In contrast to study material available over Internet, MOOCs follow a well defined structure interspersed with quizzes and assignments, providing the learner an experience similar to that of an organized curriculum. MOOCs have played a revolutionary role in reaching a far diverse and vast student audience than what a traditional classroom based model can allow. The ability to choose courses from universities all across the globe offered by reputed professors and to be able to work through it at one's own pace are a few lucrative features that has attracted not only students but also professionals working full time, people who aspire to get a new job or change their career, women taking breaks from work and alike.

2 Introduction

One of the primary reasons for the popularity of MOOCs is that it can reach a diverse student population. This advantage also poses a major challenge for MOOCs in making a long lasting positive impact on people coming from different backgrounds. The well defined structure and unavailability of standardized pre-requisites, often hinder the progress for learners coming to the course from a different field of study. The learning structure adopted by the current MOOCs model is static and is ineffective for people with different learning abilities.

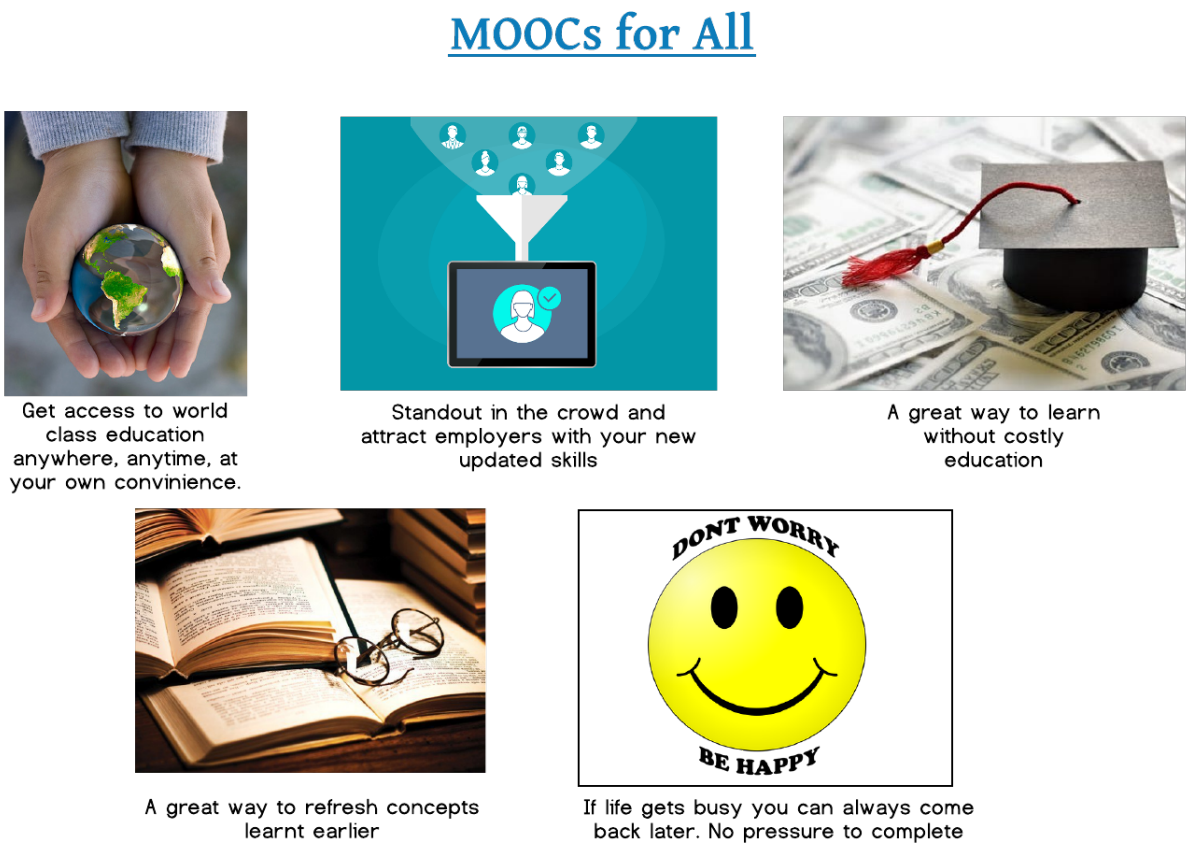


Figure 1: Benefits of MOOCs

The interaction between learners and instructors in a physical classroom setting has been found to be more intense and allows the learners to learn more efficiently, especially because it is adapted to the strengths and weaknesses of each learner [1]. an increased level of preparedness and ascribe high value to the conventional classroom mode of learning. The absence of the physical interaction in MOOCs proves to be a barrier for many learners. The lack of availability of a proper communication channel between the instructor and the learners often results in learners feeling stuck or lost at a particular section, quiz, or assignment. Moreover, the inability to properly validate the progress and improvement of particular skills in the absence of instructor feedback causes some learners to lose the motivation over time resulting in disengagement and high dropout rates. For some other learners, the lack of proper feedback manifests in other ways where they perceive their knowledge level to be higher than their actual knowledge level. This knowledge gap becomes evident when the learners attempt to apply the learning in a real world scenario and discourages them from taking another MOOC course in the future.

We present a hypothesis that there is a need for a pedagogical learning solution that

can be customized to cater to the needs of every individual as opposed to a static module that tries to work for the entire population. The main focus of our project is to glean on the broad insights revealed from historical data about the learning path of a large number of students on similar courses and offer solutions to improve the efficacy of learning process in an online setting by proper utilization of these insights. We aspire to personalize the learning path for every learner based on how they interact with different course elements.

3 Research Methodology

3.1 Understanding User Needs

In this section we will describe our process for finding a potential solution to user problems on MOOCs platform. Our entire process can be categorized into two phases: 1. Secondary Research 2. Primary Research

3.1.1 Secondary Research

We analyzed and studied some existing research that has been done in the space of online education to better understand a MOOC user, how MOOCs has benefited its users, learner pain points, and how machine learning can help in improving online learning experience.

Studies have shown that learners can be categorized into mainly two types – Career builders and Education seekers [2]. These learner profiles emerge as a result of different underlying motivations. One motivation is to get a new job or advance in their current job and the other was to seek academic or educational benefit such as gaining knowledge in a particular topic or skill or gaining a credits toward some course. Most learners who completed courses have reported to gain benefits of some kind and particularly people from developing countries and lower socioeconomic status benefit more frequently than others [2].

Problems with MOOCs include poorly designed user interface that is difficult to use, lack of collaborative learning environment and impersonal environment that is not designed for each individual learner [3]. These problems lead to high dropout rates in MOOCs. Poor user interface leads to drop in motivation among users as they spend a lot of time learning how to use the application before learning the actual course.

Another problem with MOOCs is that it does not provide the same quality of interaction that is possible in a traditional setting. This inadequate interaction hinders the benefits of knowing the learner, outlined by Knowles - this study also states that learner behavior is influenced by a combination of the learner's needs plus the learner's situation and personal characteristics. Other concerns include: 1. Global Achievement gap - The success rate of MOOCs is not equally distributed across different geographical regions. This global achievement gap could be caused by barriers such as less broadband Internet access, formal education, and English or other language proficiency. 2. Exacerbated social identity threat [4] - Students may suffer from the cognitive burden of wrestling with feeling unwelcome in

a MOOCs platform while trying to learn and, therefore, underperform.

Personalization is important as most MOOCs users come from different educational backgrounds, have different levels of knowledge on the topic they are trying to learn and also have different learning styles. Recently, the focus of MOOCs education research has been to introduce or improve personalized and adaptive learning mechanisms using machine learning.

Our secondary research also revealed that there are different types of Personas that can be found among MOOCs users.

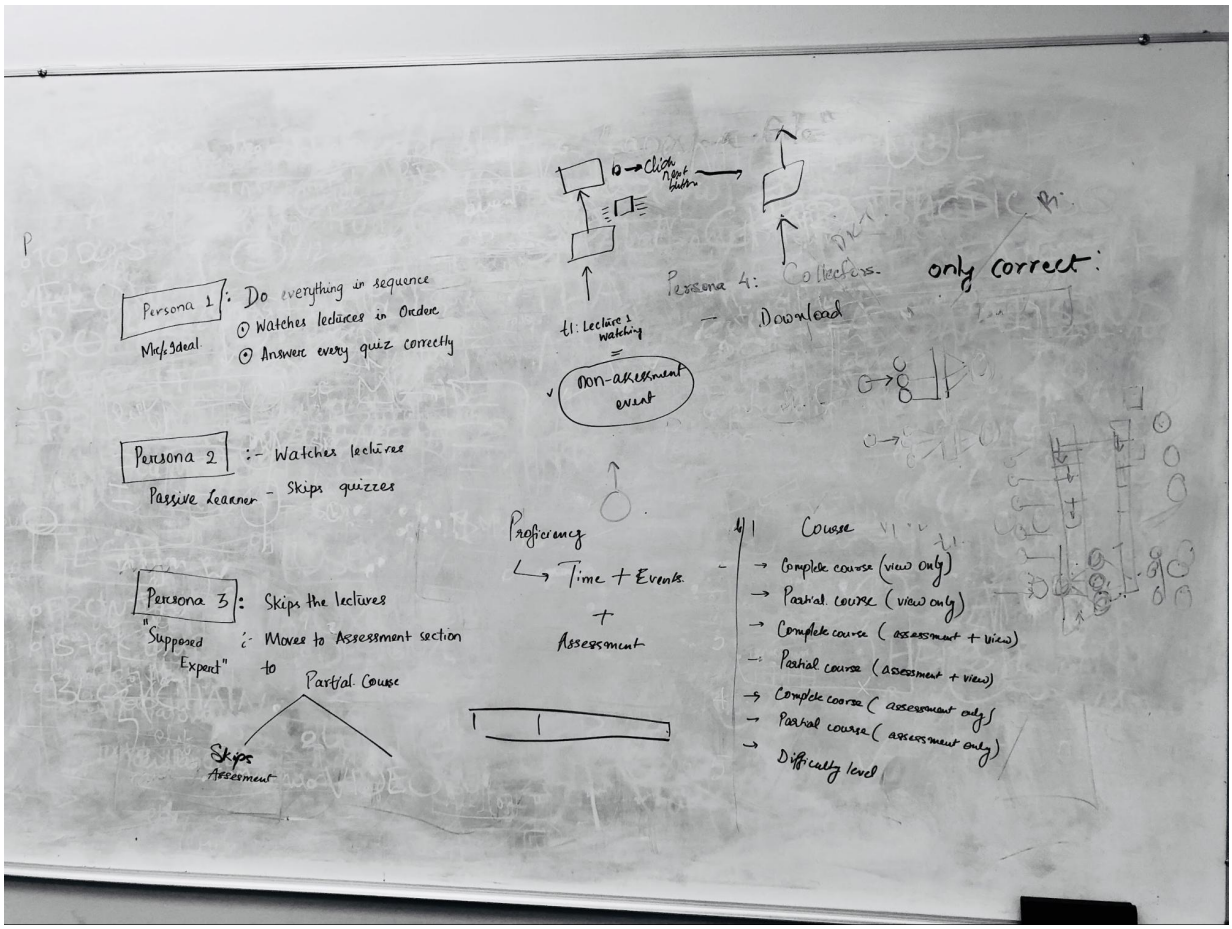


Figure 2: Persona Development on whiteboard

We identified the following MOOC user personas:

1. Persona 1: (Ideal Learner) - Do everything in sequence - watches lectures, takes quizzes and assignments without skipping anything.

2. Persona 2: (Passive learner) - Only watches lectures, skips quizzes and assignments.

3. Persona 3: ("Supposed" expert) - Takes quizzes assignments and watches only a few lectures.

4. Persona 4: (Collectors) - who download videos, don't know what they do.

5. Persona 5: (Bystanders) - Activity is below threshold.

We created Proto persona for three of our primary personas which we identified to target. Personas 4 and 5 are outliers whose motivation cannot be clearly understood [5]. This exercise will help us in better understanding our target audience and what their needs are and how they behave. From this user-centred design process we also hoped to gain clarity and focus in our project. We will describe our targeted personas in detail below:

1. Sketch and Name Alicia 	**2. Behavioral Demographic Information** • 35 yrs old • Married mother of 2 • Loves spending time with her children • Took a break from work and trying to learn new technology to get job • Doesn't have time for full time college and uses online courses for flexibility.
3. Pain Points and Needs • Has trouble understanding new concepts and goes back and forth • Needs reassurance for learning • Gives up if the learning curve is steep. • Needs a guide to understand knowledge gaps and suggest resources. • Being a full time mother, she wants to spend her time efficiently, while learning a course online.	**4. Potential Solutions** • Review pages before moving on to each section to help inform her about sections that she might need to learn more before moving on to the next section. • Skill progress bar which shows the knowledge gaps.

Table 1: **Proto Persona 1 - Alicia**

1. Sketch and Name Frank 	**2. Behavioral Demographic Information** • 30 yrs old • Single • Product manager • Loves to travel • Overworked
3. Pain Points and Needs • Wants to a learn a new topic that will help him boost his career and help him communicate with his engineers better. • Being busy does not leave him enough time to learn the subject/topic in depth through online courses. • Only has time to skim the lectures and not do the assignments.	**4. Potential Solutions** • The online tool suggests the user the basic course content without the assignments that will allow him to achieve basic proficiency in them. • Gives him the opportunity to answer a basic proficiency test at the end of the course.

Table 2: **Proto Persona 2 - Frank**

1. Sketch and Name Jason 	**2. Behavioral Demographic Information** • 40 yrs old • Senior software developer • Married father of 2 • Loves photography
3. Pain Points and Needs • Likes to solve problems and quizzes in programming topics in which he's an expert but does not want to watch lectures or just skims through them. • Doesn't have time to watch each and every lecture given his busy schedule and commitments. • Watch only advanced topics and skips most of the basic parts. • He needs reassurance of the fact that he's an expert in the field and has advanced knowledge than others.	**4. Potential Solutions** • Customized learning platform with suggested topics for learning from which he can choose topics of interest thereby saving time. • Customized quizzes based on the expert level - basic, intermediate and expert. • Progress bar showing his scores/skills compared to others in the course could reassure his expertise.

Table 3: **Proto Persona 3 - Jason**

3.1.2 Primary Research

The goal of our primary research was to get a deeper insight into the learner pain points, verify our hypothesis that personalized learning can address some learner pain points and improve overall user experience and discover specifically how personalized learning can be

best applied to MOOCs to solve user problems. The primary research we conducted can be divided into two phases – Generative phase and Formative phase. For this project, summative phase of the research is out of scope.

- **Generative Phase - *What to build:*** Our research goals were to conduct primary research to find out about general pain points that a learner experiences during the process of learning through an online platform. In this phase, we conducted surveys and interviews of MOOCs users.

- **Formative Phase – *How to Build:*** Our findings from previous surveys and interviews corroborated the secondary research findings that there is a need for making MOOCs platforms more engaging by tailoring it to individual needs. We started the development of a machine learning model the details of which are described in section 4. We also conducted cognitive walkthroughs with an expert to evaluate our paper prototypes and low fidelity prototypes. Using the feedback from cognitive walkthroughs, we conducted another round of survey and interviews with a focus on personalization and to validate if our design considerations will satisfy user needs. Using this data, we brainstormed some designs that we tested out through usability tests.

- **Summative Phase – *How did it do:*** We are currently working on integrating the software code of our product with the MOOCs platform. Research methods like Usability tests and A/B tests may be used to evaluate how well the product is received.

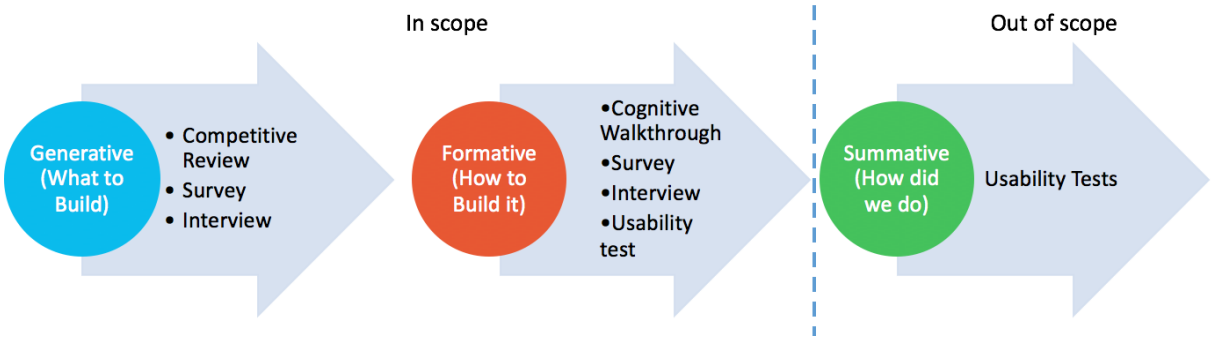


Figure 3: Flow-chart of our Research Process

3.2 Design Process

In this section we discuss in depth how we conducted our user research and how our designs evolved.

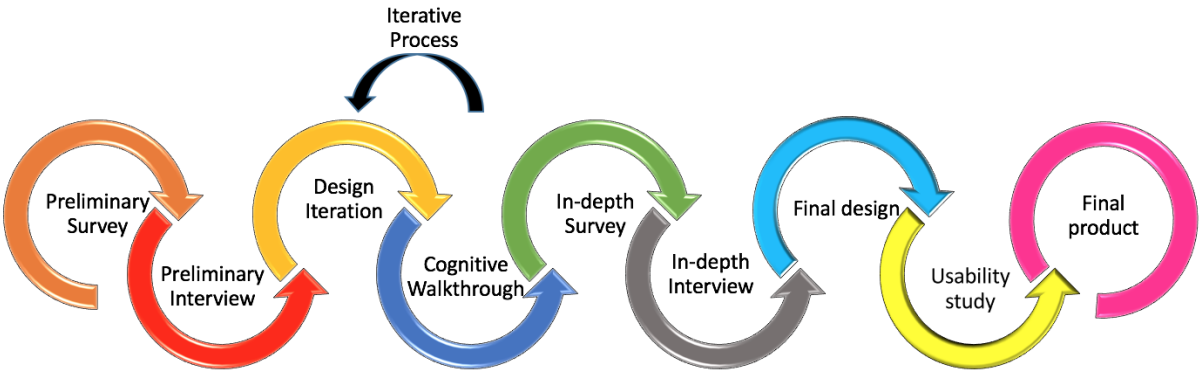


Figure 4: Flow-chart of our Design Process

3.2.1 Generative Phase

As discussed above, our secondary research findings brought up the need for making MOOCs platforms more engaging and personalized. Many leading MOOCS providers have been evolving these platforms to address these issues. Competitive analysis of some famous existing MOOC platforms especially with respect to the features aimed to increase engagement is discussed in figure5.

- **Coursera:** Coursera is currently the largest MOOC platform with more than 2700 active courses and has a user base close to 30 Million. It allows users to enroll in either self-paced (on-demand) or timed classes, ranging from four to twelve weeks. Recently, Coursera has formally announced a new search tool enabling users to search directly for skills they want to learn and receive recommended courses from the platform. Coursera's well-administered discussion boards are lively, collegial, and generative and is supported by an unpaid mentor community who help students through the courses.

  For some courses, the assessment offered by Coursera is often found to be inadequate by many users. Significant barriers in terms of time, money, and support restrict the entry for junior faculty and small institutions to the Coursera platform.

- **Edx:** Along with the learning platform, EdX also provides an open source platform (Open edX) that enables developers to build and share assessments. However, this platform still lacks any form of personalized feedback to students and simply informs them about correctness of quizzes and links question concepts to course resources. The discussion section has many useful features, such as, searching, upvoting, following, and flagging responses. However, some users found it to be lacking modernity and compared it to a "late-nineties bulletin board" [6] that is hard to use.

- **Udacity:** Udacity shifts slightly from academic style classes and puts more focus on vocational courses. Udacity also offers a collection of timed courses, termed as

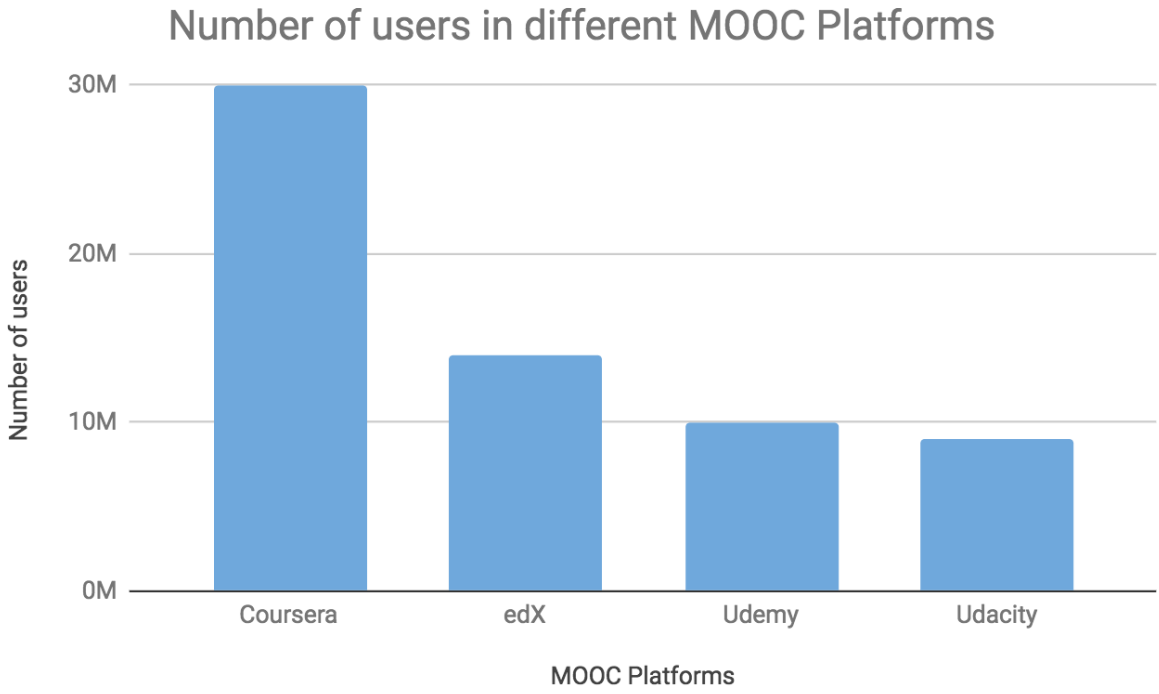


Figure 5: Number of users in popular MOOCs platforms

nanodegrees, that are tailored to the employment needs of its corporate partners. Udacity has initiated pair instructor courses, where two instructors deliver the material in a more interactive setting by explaining to each other. Udacity does not provide any feedback to learners in the free courses. They have some paid mentor roles to help students through the courses.

- **Udemy:** Udemy has a varied catalog of self-paced courses that enable professionals to share their expertise. Many of their courses are short and can be aptly described as tutorials. The assessments are not well-bodied but they provide links to the associated resources for incorrect responses. However, this is available only to the paid users. Although the platform provides discussion forums for each course in the sidebar, they are rarely used by the students and do not see much participation. This can be attributed primarily to the lack of careful scaffolding and moderation. For many of the course videos the captioning is not available.

3.2.1.1 Preliminary Survey

Survey: Our primary research goal for the survey was to understand what users find motivating and demotivating in MOOCs courses. We received about 56 responses for this survey.

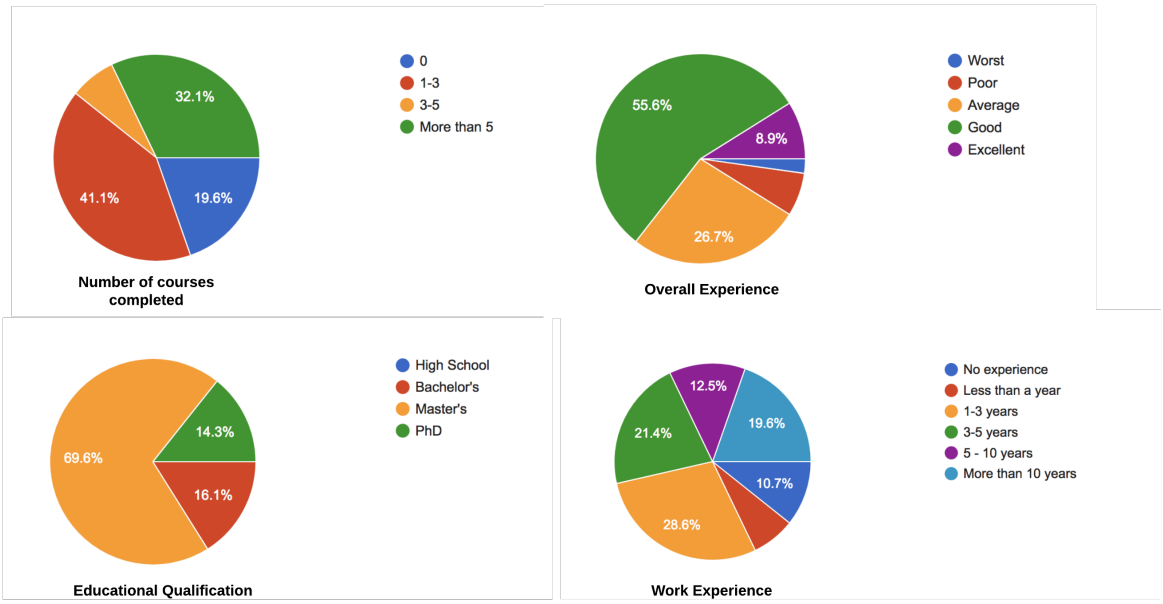


Figure 6: Demographic of the survey respondents

About 80% of our respondents were currently enrolled or were enrolled in at least one online course and also having been using these platforms for over a year. Majority of the respondents were in the age range between 21 to early thirties.

The survey responses demonstrated that some of the common reasons people take online courses were: one can learn in his/her own way based on one's preferences, easy way to learn from experts, can be accessed from anywhere and at anytime, self paced, affordable, to learn new technologies etc. From the survey we found that some motivating factors to complete courses corroborated with what we found from our secondary research. Majority of the respondents reported that learning a new skill to improve their careers and learning skills to help in their academic courses were major motivating factors to complete a course. Some other motivating factors that were reported in the survey were - Refreshing skills, getting a certificate, curiosity to understand a new topic etc.

Among factors that were responsible for not completing a course, majority respondents reported that lack of time was the biggest factor. Other major factors that contributed to high drop outs were – Users who wanted to learn only part of the course content, did not fit with the respondents' style of learning, poor user experience and course content. Survey responses also gave us an insight into what the users were looking for in an online learning experience. (See Appendix A for survey questions)

Survey Findings: We were able to identify four broad areas where MOOCs can be improved, see Table 4.

Thus, based on our survey responses, we thought of designing an interface that makes

Time	Social Angle	Motivation/Incentives	Feedback
• Indexing the video so that I can jump to different sections quickly • Design the course for super interrupted learning	• Peer learning • Community experience • Live interaction with people who are currently taking the course • Human interaction	• More incentives for busy people to finish their learning • More assignments and challenging assignments • Competition and good quality tests	• More feedback from instructors • Mentors for courses • Ability to interact with instructor

Table 4: Survey Findings

the process of online learning more effective and more efficient, as lack of time was a major reason that contributed to course drop outs. Based on the improvements people wanted in an online course, we found that personalization of MOOCs courses would make the process of learning through MOOCs more efficient.

3.2.1.2 Preliminary Interview

Interview: The research goal for these interviews was to gain a deeper insight into the process of online learning of experienced learners. We conducted about three semi structured in-person interviews. Our screening criteria for candidates was that the candidates should be familiar with MOOCs or any online learning process. The structure for the interview consisted of - a warm up section concentrating on what made them choose an online learning platform, then focusing more on what makes it hard/easy for them to learn online, deep focus on what motivates and demotivates them in an online learning environment and a wrap up section on how online learning experience can be improved. (See Appendix B for interview questions)

Interview Findings: The interviews we conducted revealed that people chose to enjoy hands-on and more interactive experience through discussion forums, getting feedback from instructors, short modules, being told what to do with clear instructions rather than being asked to read. In addition, learning through execution was also a key component.
It was found that when a course suddenly became hard and required some prerequisite

knowledge or was too long, it affected the overall experience and the learning process, which would often lead to drop outs. Sometimes, if the learning curve to understand an advance topic in the course is steep, that can also be a demotivating factor and would often lead to drop outs or would result in the learner taking a break from the course. If the learner is still motivated enough to continue the course, it would often result in increased time spent in searching and reviewing relevant content within as well as outside the course to strengthen basic concepts before attempting to tackle advanced concepts in the course.

3.2.1.3 Design Iteration 1

Thus, at the end of our generative phase, we brainstormed among ourselves and based on the survey and interview findings, we discovered that one main activity that learners spend a lot of time on, was going back and forth between sections. This often causes them to give up in the middle of the course because the content got too hard or because they lost touch of it.

From our experience and research, we had also found that most online courses were structured in a way that starts with easier concepts which later on are used to built upon to learn more advanced concepts/topics. A learner who has not fully understood the basic concepts will later on struggle when more challenging/hard topics are introduced. The quizzes at the end of every section fall short to adequately validate the knowledge level as they are tend to be short and can be skipped to move to next section. Thus, we realized that despite end of section quizzes, there was still a knowledge gap that existed before learners moved on to more advanced topics in the course, which was one of the main reasons for the dropouts or poor user engagement. So we targeted our efforts to minimize this gap.

One way we thought we could achieve this was using personalization in MOOCs. We thought that by using machine learning to create a personalized review page generated at the end of each section, after every quiz, is one way to inform the user about knowledge gaps and possible actions to remediate the gaps.The idea was that the combination of both will guide users through the course without letting them feel lost or spending insane amounts of time in going back and forth in the course. Based on this idea, we came up with a prescriptive solution of creating Review Pages with following features:

- Skill level – that informs the user their skill level in all skills that they have encountered so far.
- Skill progress – Visualization that indicates, with regards to a particular skill, how much course content has been covered by the user and how much can be expected in the future sections of the course.
- Suggested review links – Based on the course navigation pattern and quiz answers, the system would suggest course resources for every skill that the user could revisit to increase his/her skill level.

Based on these, we created some design prototypes on paper.

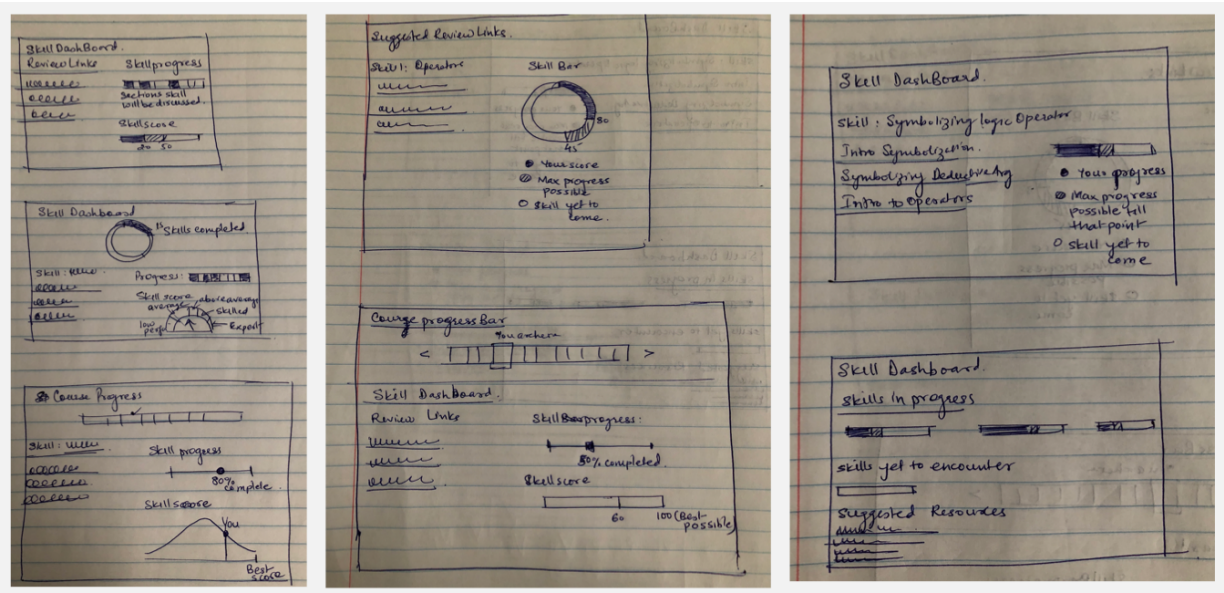
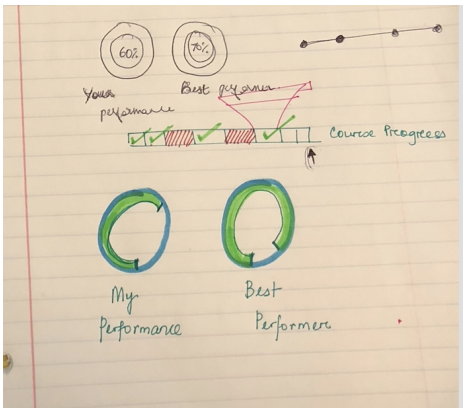


Figure 7: These are the pictures of some designs that we developed during brainstorming sessions

The main designs we selected among these prototypes included a skill bar for every skill, which represented the learner's score for that particular skill, the maximum score that can be achieved on that skill and amount of skill that is yet to be covered in the course.

The design considerations for skill progress bar included a horizontal bar representation of skill progress as we thought it is more intuitive for the user to perceive temporal skill progress in a course. Another design consideration for the skill progress bar was by depicting the skill progress using circular rings. We chose to use rings as another design consideration as it is an intuitive way to visualize progress, as seen in Apple watch's activity rings.



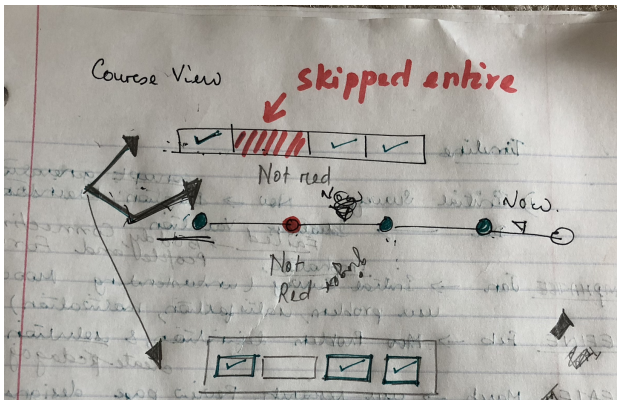


Figure 8: Pictures of some designs that we developed during brainstorming sessions (contd.)

The assumptions with these designs was that the course content was of good quality and that there exists an pedagogical learner or an ideal learner, who could view and understand the course content the first time and could answer all quiz questions correctly.

3.2.2 Formative Phase

3.2.2.1 Cognitive Walkthrough

The goal of cognitive walkthrough was to evaluate the learnability of the review page from the perspective of a first time user. The target profile of a first time user is a MOOCs learner who is interested in learning a new topic through a MOOCs course by completing the course.
After brainstorming over our paper prototypes, we conducted the first iteration of cognitive walkthroughs with an expert in the area of MOOCs with the paper prototype. After incorporating the feedback from our first cognitive walkthrough, we then iterated on our design and conducted the second iteration with low fidelity prototype created in Balsamiq.

3.2.2.2 Design Iteration 2: Low Fidelity prototype

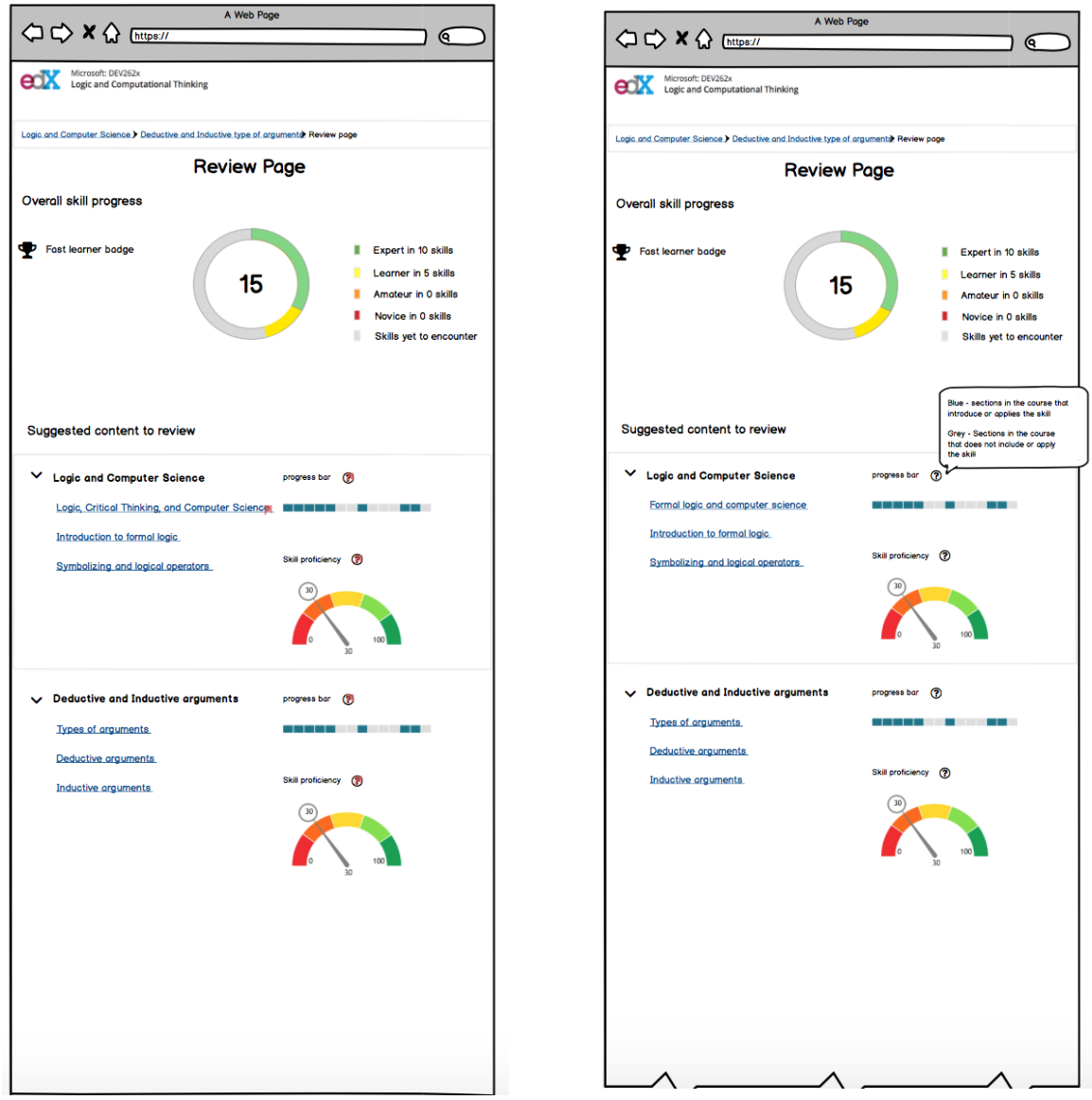


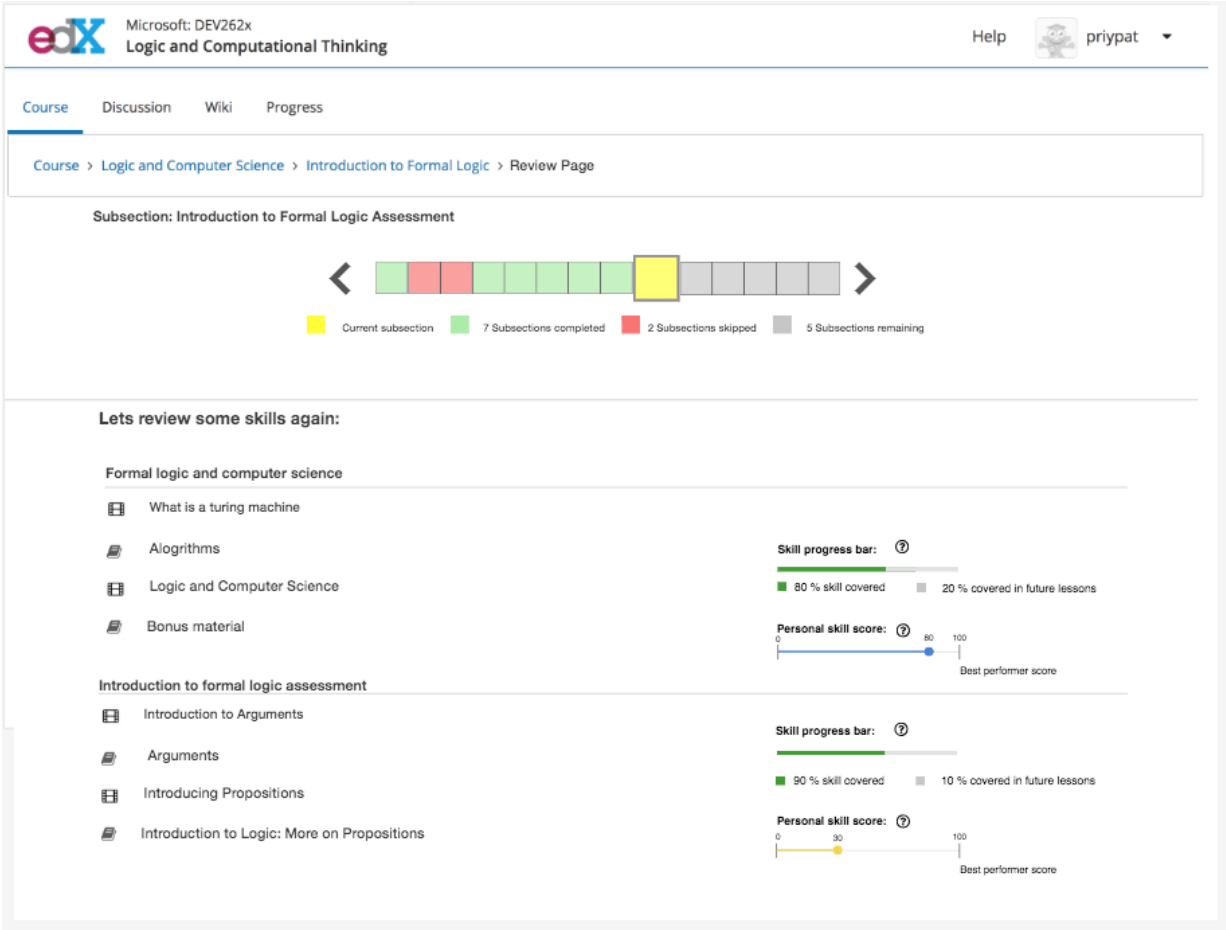
Figure 9: Low Fidelity Prototypes

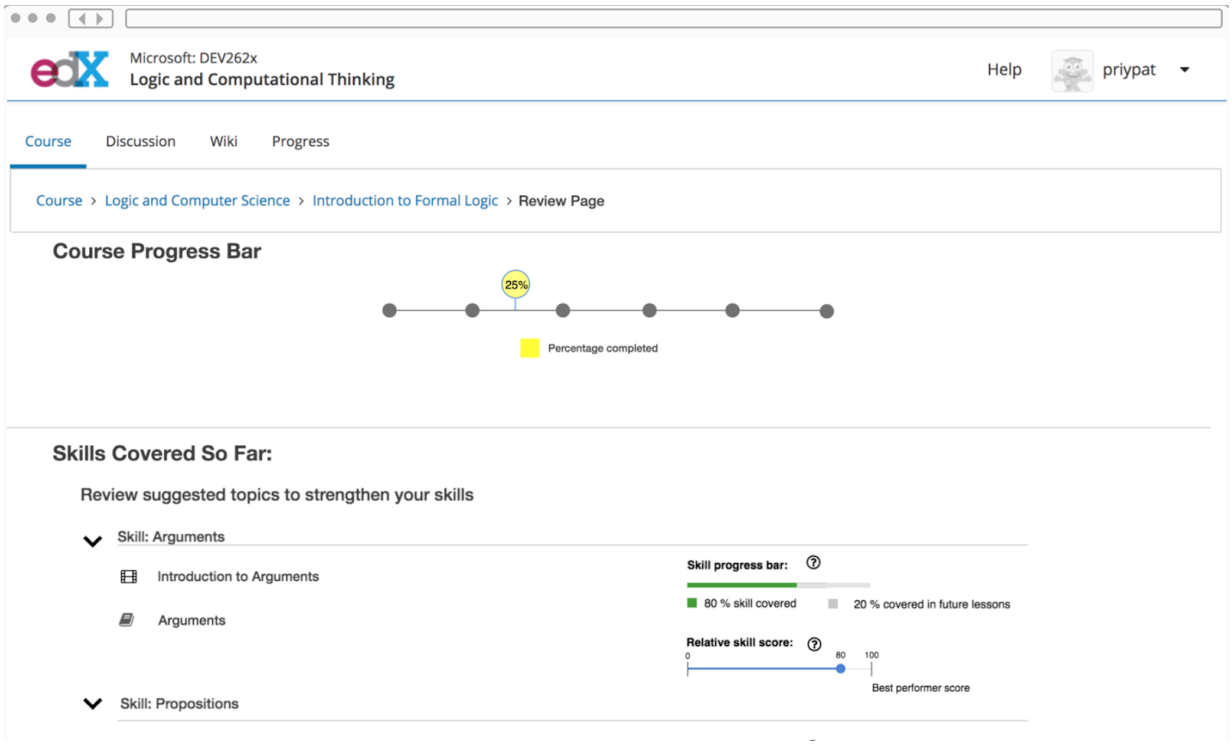
Findings: From our cognitive walkthroughs, we found that the skill level and skill progress representation in our paper prototype designs proved confusing to the expert. Based on this feedback, for our second iteration, we decided to decouple skill level and skill progress features and decided to visualize them separately. In addition, the low fidelity design in Balsamiq also included the visualization of skill dashboard that gave the learner a snapshot of the skills achieved and it also represented his/her's skill levels in each skill.

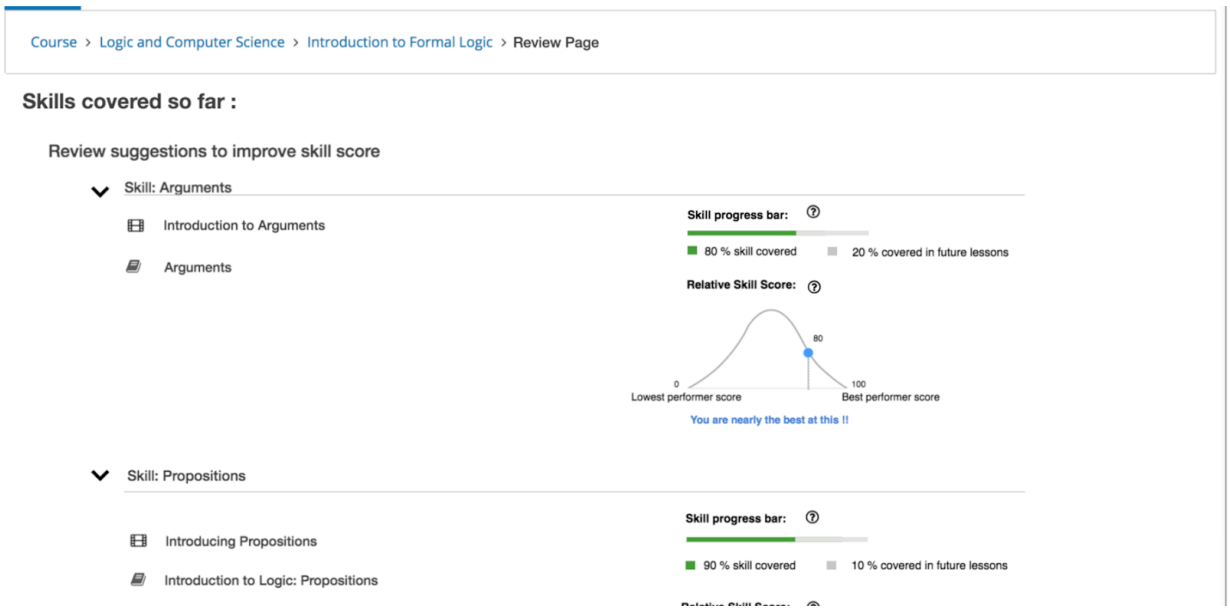
After conducting a walkthrough with another expert with the low fidelity design in Balsamiq, we found that visualizing skill progress as shown above, was not very intuitive and could be confusing to the users. We also realized that it would be challenging to visualize section wise navigation for every skill, as on an average there were more than 20 sections in every course. Thus, it would have been hard to display how a skill progresses in the course. Another recommendation made by the expert user, was to include a course progress bar, that displays course progress after every section quiz in the course providing a motivation to the users that they have come so far in the course and should not give up.

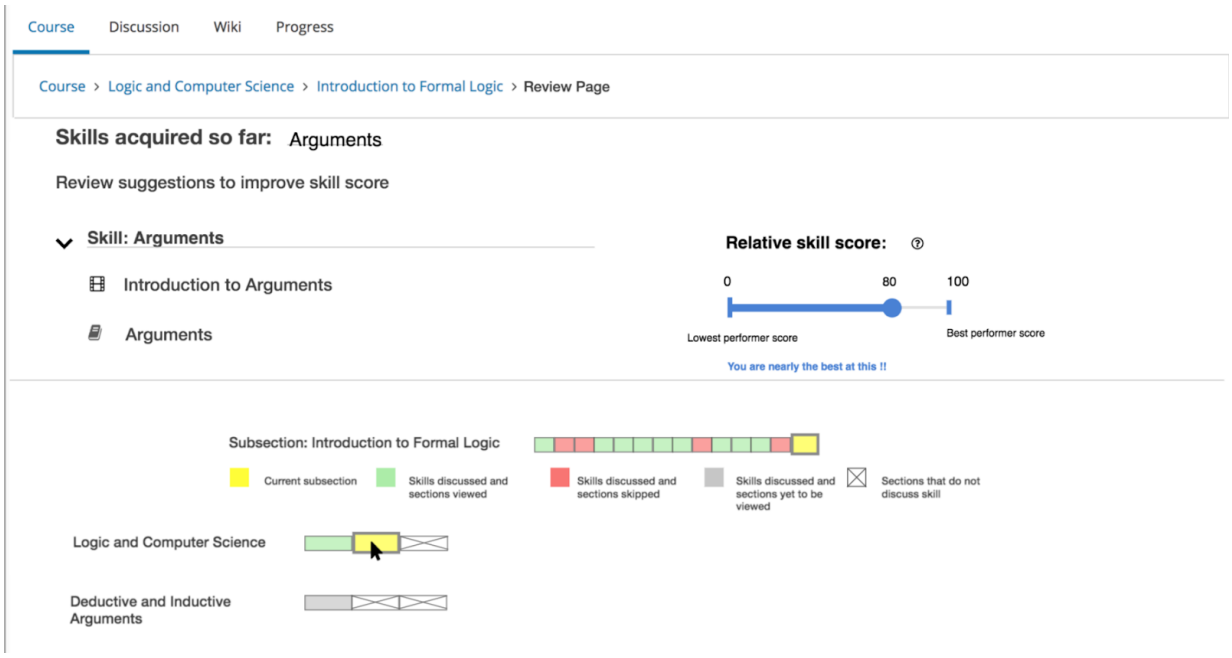
Thus incorporating the feedback from cognitive walkthrough in our third design iteration we decided to include a course progress bar that displayed the learner's current position in the course at the course subsection level, section level and topic/chapter level. In addition, we retained our features from our second design iteration - skill progress bar, skill score and suggested review links. During our design brainstorming session we experimented with a lot of designs for the features mentioned above. Below are few screens that we created as we brainstormed various designs during our third design iteration process.

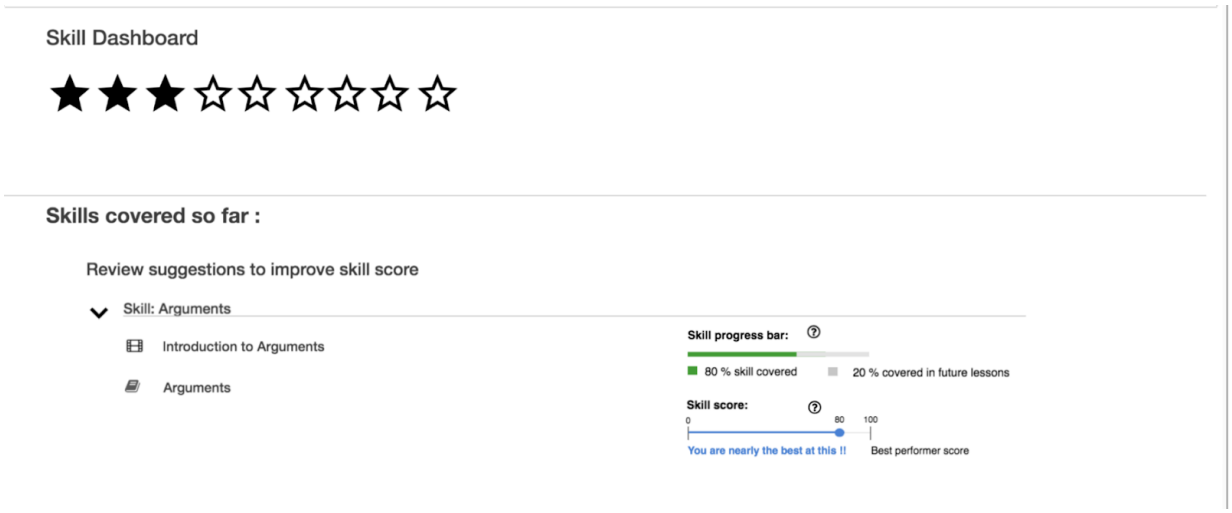
3.2.2.3 Design Iteration 3: High Fidelity prototype




Microsoft: DEV262x
Logic and Computational Thinking
Help
priypat
Course
Discussion
Wiki
Progress
Course › Logic and Computer Science › Introduction to Formal Logic › Review Page
Course Progress Bar
25%
Percentage completed
Skills Covered So Far:
Review suggested topics to strengthen your skills
Skill: Arguments
Introduction to Arguments
Arguments
Skill progress bar:
80 % skill covered
20 % covered in future lessons
Relative skill score:
0
80
100
Best performer score
Skill: Propositions


Course › Logic and Computer Science › Introduction to Formal Logic › Review Page
Skills covered so far :
Review suggestions to improve skill score
Skill: Arguments
Introduction to Arguments
Arguments
Skill progress bar:
80 % skill covered
20 % covered in future lessons
Relative Skill Score:
80
0
100
Lowest performer score
Best performer score
You are nearly the best at this !!
Skill: Propositions
Introducing Propositions
Introduction to Logic: Propositions
Skill progress bar:
90 % skill covered
10 % covered in future lessons


Course
Discussion
Wiki
Progress
Course > Logic and Computer Science > Introduction to Formal Logic > Review Page
Skills acquired so far: Arguments
Review suggestions to improve skill score
Skill: Arguments
Introduction to Arguments
Arguments
Relative skill score:
0
80
100
Lowest performer score
Best performer score
You are nearly the best at this !!
Subsection: Introduction to Formal Logic
Current subsection
Skills discussed and sections viewed
Skills discussed and sections skipped
Skills discussed and sections yet to be viewed
Sections that do not discuss skill
Logic and Computer Science
Deductive and Inductive Arguments


Skill Dashboard
Skills covered so far :
Review suggestions to improve skill score
Skill: Arguments
Introduction to Arguments
Arguments
Skill progress bar:
80 % skill covered
20 % covered in future lessons
Skill score:
0
80
100
You are nearly the best at this !!
Best performer score

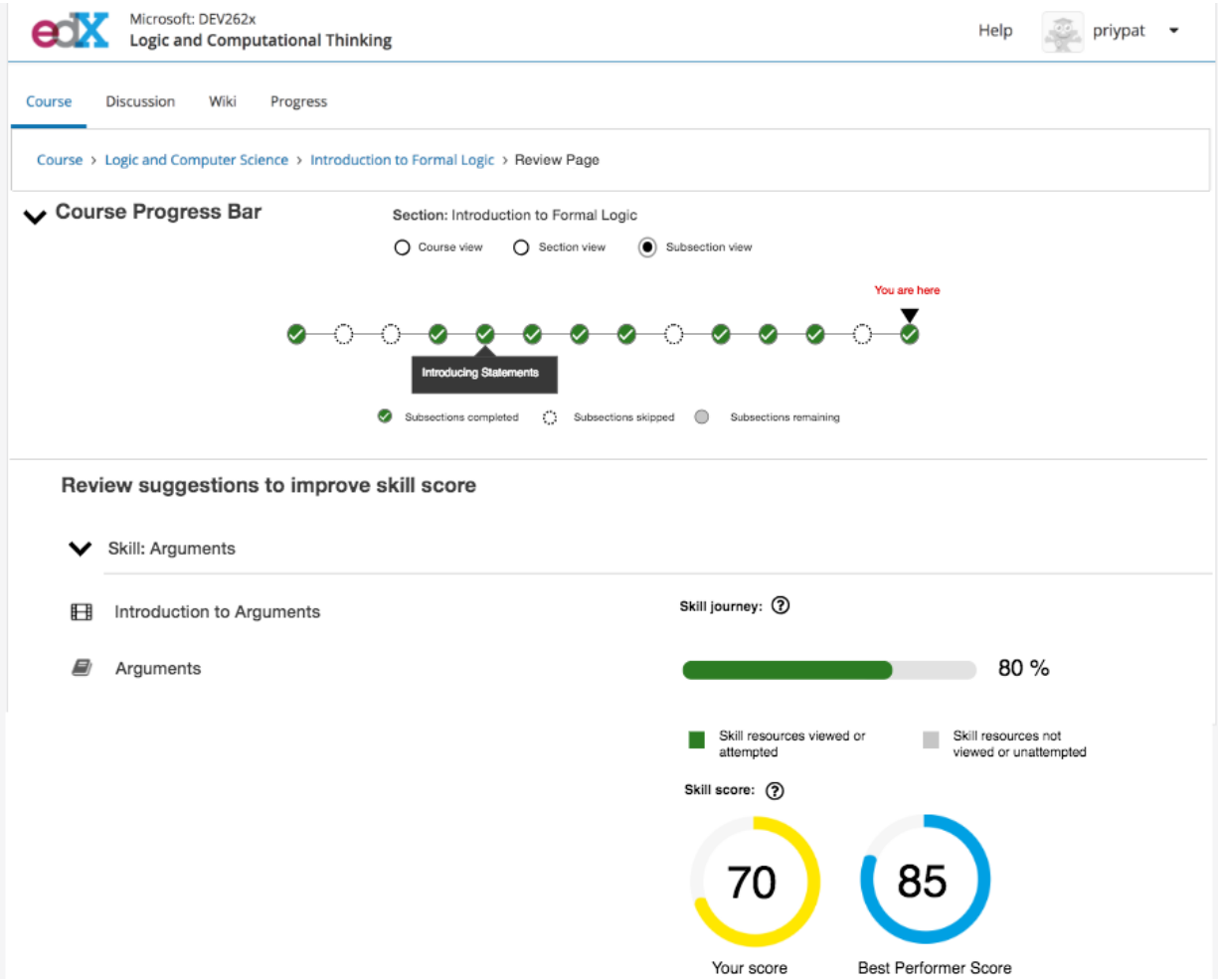


Figure 10: High Fidelity Prototypes

3.2.2.4 In Depth Survey

The goal of the survey was to get more detailed information on a MOOCs user's learning process and how they evaluate themselves for the skills taught in a MOOCs course. This survey was more focussed on assessing the utility and value of the various features in our Review Page design. We had 77 respondents in this survey. (See Appendix C for survey questions)

In Depth Survey Findings: Almost 80% of the respondents felt quizzes, assignments, videos and reading materials were at least moderately important for them in MOOCs, indicating that most of our respondents possibly belong to one of the three short-listed Mooc learner personas described earlier. Majority of them reported that they tend to revisit resources on these platforms; students mostly do it for difficult topics that they don't understand while professionals mostly do it for reinforcing the understanding of a topic further. Only 30% of the respondents actually reported to use course quizzes and

assignments for evaluation, majority users have other metrics, like being able to explain concepts to others or being able to apply learnt concepts in external applications. This gives us some basis to justify our skill knowledge tracing feature. The skill knowledge level can act as an automatic and uniform checkpoint enforcing pedagogical feedback irrespective of whether a user attempted quizzes or not.

When asked directly about the action they take on getting a question wrong, majority respondents chose to revisit lectures, indicating that there is a stronger tendency to revisit lectures if the option is very evident. This is further reinforced by responses where more than 80% respondents reported some level of difficulty in locating resources to revisit on online platforms, meaning although users try to go back to topics, they probably give it up because it's hard to find the relevant resources. This helped us vett our use case for the Suggested skill review links which can be helpful in nudging users to go back and learn things better before moving forward in the course.

More than 70% respondents indicated that it is very important for them to know how well they are progressing in the course. The status of progression was found to be of higher importance for student respondents than for professionals. At least 80% of them value some kind of feedback: teacher, mentor or autograded, validating our proposed use case of the Review page as feedback. More than 70% users showed at least moderate importance for relative performance on MOOCs platforms. This reinforces our design decision to include best performer score in our review page.

3.2.2.5 In Depth Interview

After the feedback from cognitive walkthroughs and spending some time brainstorming on few design ideas we decided to conduct interviews with the primary goal of gaining a more in depth understanding about the process of online learning specifically through MOOCs courses that followed a quiz based assessment format. We also wanted to verify our hypothesis that a feature like review page could help in improving the efficiency of the online learning process in MOOCs.

Through a semi structured interview, we aspired to uncover the pattern of use for each of our interview participants and learn more about their behavior, likes and dislikes in these platforms. Our primary motive was to gather information about the learners' feelings, motivations, the aspects which they found to be particularly helpful in their learning experience, how they evaluated their skills learnt in the course and what they felt could be done to enhance this experience further.(See Appendix D for interview questions and transcript)

We conducted ten user interviews and there were many similarities which were observed and hence we chose to include the description of the analysis that was for three of our representative personalities who exhibited typical characteristics.

Interview Findings: All our interview candidates had taken and completed multiple MOOCs courses. The process of learning a topic through MOOCs differed among the interviewees and it heavily depended on their reason for taking up the course. All of them

had at times viewed the entire course content, attempted quizzes/coding assignments and completed MOOCs courses to learn a new topic that they were deeply interested in. However, it was also seen that all participants had the need to skip sections, mostly because they were familiar with the sections that they skipped.

What made most of them choose MOOCs was that they expected good quality course content on MOOCs and that they could take the courses anywhere, anytime and that they were self paced. The interviewees that were pursuing a Masters degree also expressed that they would often take a MOOCs course to augment what they had learnt in university courses or to help them pass course exams or certifications. Two out of seven interviewees also emphasized the importance of instructors. They mentioned that good and engaging instructors were a big motivating factor to continue a course. One interviewee also expressed that if he was happy with an instructor, he would also be motivated to study more courses by the same instructor. Other motivating factors that made almost all participants continue with a course was that most of the courses that they liked were structured really well and had short sections/videos that were easily digestible. We also found that there were several other factors that motivated each candidate individually. One interviewee mentioned that he would particularly be motivated to stay in courses that structured the content such that each continuing section build up on the previous section. He found that he was often motivated to stay in a course if it got challenging as he progressed through it. Another interviewee mentioned that accountability and a deadline usually motivated her to stay in the course.

Some factors that demotivated the interviewees were times when the instructor is not engaging enough or if it was hard to navigate through section or skip sections. One interviewee mentioned how he dropped out of the course as it did not allow him to skip sections without completing a previous section. One participant also mentioned that he had dropped out of a course if the section assumed that the candidate would know certain skills. He gave an example of a course where he discovered in the middle of the course that the section required prior knowledge on a particular topic. He went on to mention that for the same reason he liked courses that at times took a survey/quiz before the course started to evaluate if the learner knows enough to proceed in the course.

When we asked the candidates on how they evaluated themselves in a course, we got variety of responses from interviewees. While some gave importance to quizzes as a form of evaluation others dismissed the importance of quizzes. The ones that did not depend on quizzes as a form of evaluation reported that if they could explain the concept to someone else or if they could apply it on the job or on some assignment they would conclude that they learnt the concept.

When asked about what makes them revisit topics or courses, most common response among the interviewees was when they wanted to refresh skills or topics. Two interviewees further mentioned that they also revisited courses to refresh skills only if they were really happy with the course and the instructor. Interviewees who were enrolled in university programs also mentioned that they chose to revisit certain courses or topics to pass certifications or exams. Some participants chose to revisit topics when they got questions wrong or if they wanted to better understand a topic before they moved on to a more difficult

section in the course.

When asked about how they value being scored relative to other learners pursuing that same course, most of them said it is not particularly valuable to know how others performed. One interviewee mentioned that she did not care how others performed as she did not know them well. She would be more interested in learning about her own performance than others. Echoing on the same thought, another interviewee mentioned that though he sees value in it, he would want to get more information than just scores. He said that he also wanted to learn more about how the score was being calculated. He explained that by saying "others perhaps may just be lazy" indicating that he wanted to be compared to other learners who are taking the course as seriously as he was. The same interviewee had also mentioned previously that he would feel happy to know when he realized that he knew more or as much as other students, who were known to be knowledgeable in the field.

Among the improvements that the interviewees would like to see in a course, the most important recommendation was having the ability to see how a topic progressed through the course, perhaps a tree diagram structure that made it easy for learners to navigate and choose sections to focus on based on a topic.

Interview Takeaways: The interview confirmed our hypothesis that people who are deeply interested in learning a new topic will go through all sections and attempt all quizzes. This was a valuable insight as we believe that our solution will be most valuable to a user who goes through the entire course and attempts all quizzes. It will also prove useful for a course that increases difficulty level of the topics in the course. Interviews also reinforced our hypothesis that people often drop out if they have not grasped concepts discussed in the course completely or have forgotten them when returning to complete the course after taking a break. In such cases, we believe that our solution to include review links to improve a score in a topic or skill would be useful. Based on the recommendations, we also found that our skill progress bar may be appreciated by the users, as it gives them an idea of the "skill resources" that are yet to come.
It was also noteworthy to find that although majority of the users thought that relative scoring is not very valuable, some responses indicated that users may appreciate being compared to users who were "just like them". Further there was also a lot of interest in knowing how the scores were calculated. This insight made us reconsider the design for our relative skill score. We also wanted to motivate the students to continue with the course by providing motivational messages to do better in the course or to reinforce that they are doing well in the course. This psychological framework of messages, feedback scores and course progress would provide a motivational effect to the users. With this insight we also decided to test this design further with usability tests.

3.2.2.6 Design Iteration 4: High Fidelity prototype

After our third design iteration, we brainstormed some more designs and zeroed in on one final design and the features that needed to be included in the review page. Our final

features included – a course progress bar, a skill mastery score, a skill progress bar and a list of links that the system suggested to the learner in order to improve respective skill mastery score.

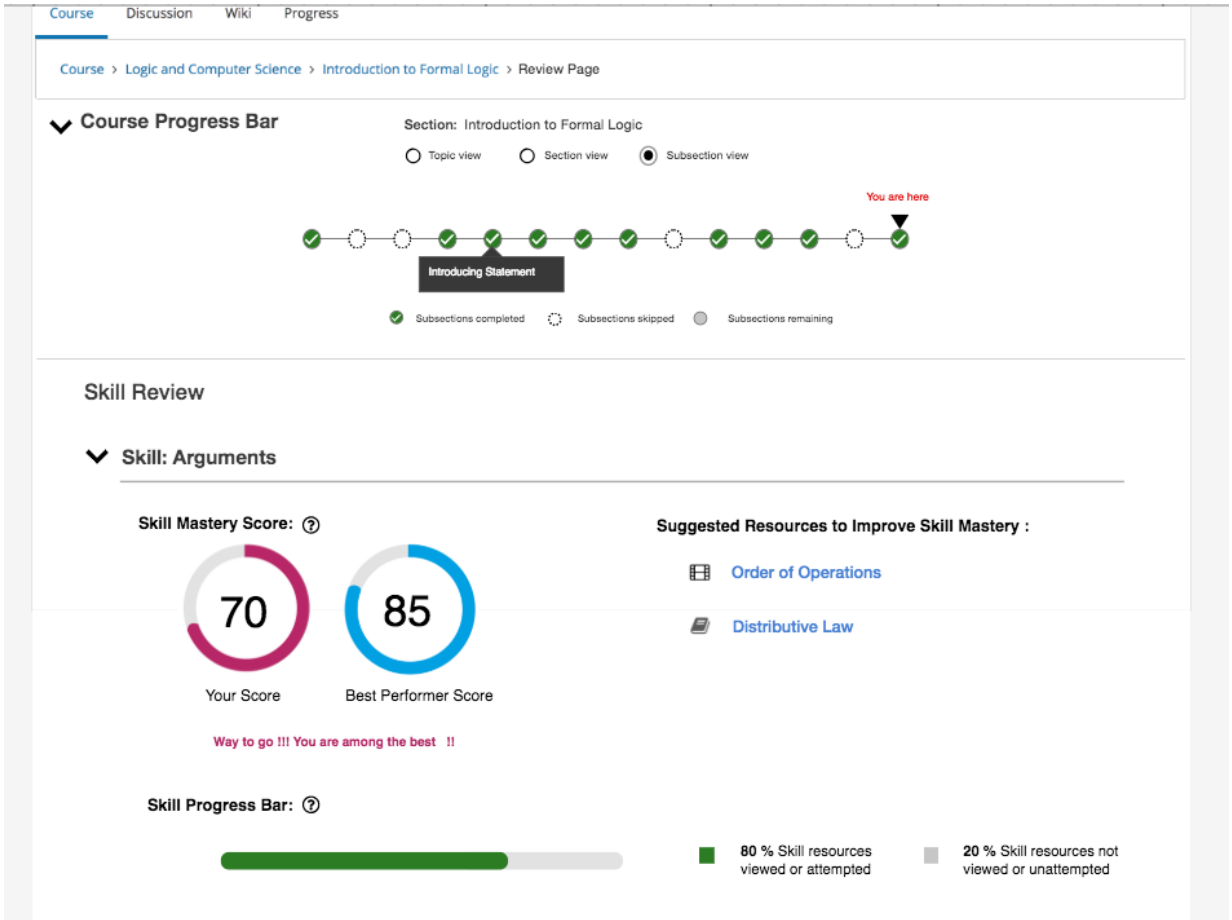


Figure 11: Final Design Prototype

Feature description:

- **Course progress bar:** A course progress bar was a way to convey to the user their current position in the course. The user could see their course progress in three views – topic view, section view and subsection view. In the final design, we decided to include white check on green circle to indicate attempted/viewed resource, dotted circle to indicate skipped resource and greyed circle to indicate future or upcoming resources.

- **Skill Mastery Score:** The role of the skill mastery score was to inform the learner about the learner's skill level relative to the best performing learner in that course.

The score was calculated using machine learning algorithm that took into account the learner's navigation patterns and the quiz responses. We chose to represent the skill mastery score as two circular rings with numerical values as we thought it would be an intuitive way for user to compare his/her score with best performer score when displayed next to each other. We also made the design decision to display a score for the user and best performer as we thought it will allow the user to not only view how his/her absolute score calculated by the system, but also view the best performer's system score.

- **Skill progress bar:** The skill progress bar is a way to inform the user on how the skill progresses through the course by displaying the percentage of course resources attempted or viewed by the user and also by displaying percentage of course resources not attempted or yet to be viewed by the user (i.e topics related to that skill that have been skipped by the learner or will be discussed in the future sections).

- **Suggested course review links:** These suggested review links, are important and valuable to the user as it indicates the areas that the system thinks the user should go through to best understand a concept before moving on to more advance concepts.

Thus, we believe that informing learners about their course progress and skill development progress in the course using above features will allow users to not only evaluate themselves on every skill but will also allow them to efficiently use their time to strengthen their skills before moving on to more advanced topics and will thus improve user engagement.

3.2.2.7 Usability Testing

We conducted usability tests to evaluate our final design to evaluate the design's effectiveness in informing users about their skill mastery levels and steps that they can take to reduce the gap between expected skill level and skill level achieved by them. (See Appendix E for usability guide)

Usability Testing Findings: Most users liked the course progress bar as it was motivating to see the status of their current standing in the course. The choice of colours for the different design elements was also appropriate as one of the users said "I will want to get all green ticks". Some liked the different view options available, while a few were concerned that too much information might make the interface "messy". The skill mastery visualization was colorful and most users engaged with it for a long time, distracting them from noticing other features. Suggested resources was one of the most likeable feature and most of our users were able to figure out what those links signified and it also matched with our initial expectation. Most users stated it would save time and effort that is involved in searching for the right material to review. The skill mastery score and skill progress bar were 2 confusing elements in our review page and different users brought in different assumptions while understanding what it meant. As we did not explicitly indicate the unit

at which the scores were calibrated, some of the users felt the skill progress bar and skill mastery level were somehow related and that led to them reading the two together. With regards to the relative score feature users were divided in their opinion. We also found out that users preferred to see average score as opposed to best performers' score as the best performer can be an extreme case and they would rely on class average statistics.

4 Model solution

4.1 Conceptual Model Development

The aim of the project is to improve student learning experience in an online MOOCs platform so that students are able to master the concepts that a MOOCs course lays down. To improve the process of learning, we need to understand how learning takes place in humans and how learning is measured. In the subsequent paragraphs we will explain how learning takes place in humans, what is the best proposed instructional method to achieve maximum learning and how we propose to use the method to improve student learning in MOOCs platforms.

In the cognitive theory of learning, learning is a continuous process. Any new concepts learnt by a person are built on the earlier concepts and components already mastered by the student. This essentially assigns a hierarchical structure to knowledge and skills. All knowledge is built from a series of prerequisite components, thus, mastery of each step prior to advancing to the next step is essential to achieve the overall mastery in a course [7]. For example, for a student to be able to master multiplication, it's very important that he/she first masters the skill of addition. In contrast if the student does not pay heed to this lack of complete skill mastery and moves ahead with subsequent chapters which would involve certain concepts of increasing complexity, there is a higher likelihood that he/she would have to struggle to learn the complex skills, than if he/she pauses to spend more time and revisits the reading materials or associated resources to ensure his/her skill level is adequate. So, in order to make the process more efficient and to ensure the learning path is smooth it is important to provide corrective feedback to the learner at regular intervals.

Every individual is different, learns at their own pace and it's important to give timely corrective feedback to students. Bloom (in The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring)[8] has shown that there is 2 sigma increase in student performance under individualized tutoring with timely corrective feedback. This idea of increased student performance under corrective feedback led to the evolution of Mastery learning as an instructional methodology. It works on the principle of continuous assessment and remedial action. According to Bloom's theory of mastery learning, diagnosis is required. For example, if a student is having problems with his studies, the cause needs to be found. Instruction should be supplemented with correctives such as tutoring, additional practice, small group study, games, or even re-teaching the material [9].

Based on this premise of hierarchical structure of knowledge and skills of a particular

subject and the use of mastery learning as the underlying pedagogical principle, we propose that in online platforms we can increase the student learning by providing continuous feedback to students. This will help students to keep track of the skill knowledge they have acquired, thereby letting them to make informed decision about moving ahead in the course or revisiting the earlier concepts. As a form of pedagogical feedback, we also propose to point students to resources, in the course, that would help them in filling knowledge gaps of a skill before moving ahead.

In order to incorporate the element of "feedback" in a course, it is crucial to set up checkpoints where the feedback can provide maximum value to the learner. These identified checkpoints will remain in a distributed or spread out format throughout the course as per our premise discussed in earlier paragraphs relating to hierarchical structure of knowledge. Quizzes including other assessment categories present opportunities for a learner to determine whether or not he/she achieved the learning objectives to the desired expectation. Hence in our research, we have chosen the "end of quiz" as checkpoint where our feedback will be integrated. The rationale behind this design choice is that when a student starts a quiz, he/she is mentally in a mode of evaluation and at this juncture the student is well situated to receive some feedback on his/her level of preparedness in the skills that was covered in the course so far. In addition to setting checkpoints for providing feedback it is essential that we should be able to identify these checkpoints with discrete knowledge components or skills or learning objectives that can be used to measure mastery in a course.

In our project, we created a taxonomy of skills taught in the course to provide feedback to students after every quiz, in the relevant skills, identified for that course. This feedback shown to the course participants is designed to comprise of two elements, information about student's mastery in a particular skill as well as the resources that a student should revisit in the course to improve his/her skill mastery level.

In order to be able to predict the acquired mastery of students at any time in the course, we use knowledge tracing. If a student shows lower levels of knowledge acquisition in a particular skill, we can provide corrective feedback on that skill/concept to allow them to improve it. In order to suggest resources for improving the skill level, we propose to use behavioral modelling and skill tagging of resources.

4.2 Pedagogical Modelling

Our main features in the proposed pedagogical model are:

4.2.1 Modeling Knowledge Tracing

In order to identify the skills which a student needs to improve before moving further in a course at any time, we are using the method of knowledge tracing. It is the method of modelling a course learning objectives as discrete knowledge components which are to be attempted sequentially by students. The objective for knowledge tracing is to predict a student's future performance based on their past activity. This is directly useful as a student's ability undergoes continuous assessment [10].

For knowledge tracing, we are using the latest Deep learning methods called deep knowledge tracing, which is the method of using Deep Neural networks in predicting the knowledge. This method uses RNNs to map student's probability of learning different skills in a course at any point of time in the course based on his response to questions at prior timesteps. The advantages of using deep neural nets in the form of RNNs is that they are dynamic models that are able learn the latent states of learning.

4.2.2 Modeling Corrective Feedback

We have to identify the resources and actions that should be taken by a student to remediate any gaps in the skills which form a prerequisite for the future course skills. In order to provide corrective feedback, we propose to suggest resources for improving the skill level. This we propose to base on the behavioral modelling of students[11] and skill tagging of resources in MOOCs. Behavior modelling is a machine learning approach that recommends next actions for a student on the platform based on the activity of similar users in the course. Once we know the skills of low mastery levels for a student at a checkpoint, we can identify all the resources in the course delivering the skill. From the resources, we identify the resources that are more likely to be performed by the student which are then shown in the feedback.

4.3 Model Development

In our research we have divided the process of exploration of a reliable deep knowledge tracing into three phases:

1. Phase 1: Study of DKT performance when its informed by the performance of student on the assessments in a course.

2. Phase 2: Study of DKT performance when its in informed by the performance of the student on assessments in a course as well as the behaviour of the student on the platform. The behaviour of a student is captured by the clickstream data of the student on the platform.

3. Phase 3: Study of a hybrid model that outputs DKT results that is probability of knowledge level of a student in different course skills as well as the expected behaviour of the student in the future on the platform.

4.4 Machine Learning Pipeline

In the proposed intervention of corrective feedback and knowledge tracing, we use machine learning for predicting knowledge levels of students in various skills of the course and to recommend resources. In the next few sections we will explain how the machine learning pipeline works especially with respect to the experimentation carried out during the project.

For the purpose of our research experimentation, we wanted to check the feasibility and working of different Deep Knowledge tracing models.

4.4.1 Data Collection

The datasets used in this study are the log data from edX MOOCs. Log data is essentially the clickstream data of the users on the platform. For experimentation purposes we had access to the anonymized data of a course called Introduction to Aeronautical Engineering (AE). For online deployment we were later given instructor access to a course running on edX Platform called Asynchronous Programming with Javascript offered by Microsoft. Data collection in a current course offering can be done using sensor APIs, which listen and record the real time data of students' activity. A similar setup has already been shown to work in a previous research of the advisor of this project [11].

4.4.2 Data Cleaning and Preprocessing

As described earlier, the data available from edX MOOCs in this study is in the form of activity logs of users. The log data collected in each edX course is in the same format. The raw log data records all events in the course as a JSON entry each time. Each entry has information on anonymous unique student id, url of the page, event type and timestamp, and based on event type further metadata is also provided eg. for event type of 'problem check', metadata includes whether the response was correct, which attempt number was this action and url of the problem page.

In our data processing pipeline we first sort all the log entries in the raw dataset by ascending timestamp order. From each log entry we get the event type and the timestamp as well as the time spent on the event. All the data is then grouped by unique student ids, such that for each student we get a chronological event stream (and event related metadata) of all his/her actions in the course.

Since we are interested in predicting the knowledge level of students in different skills taught in the course, its very essential to develop a single fixed skill taxonomy for each course that uses this intervention. During the project, we created taxonomy for a few courses where we expected to deploy our intervention. After developing the taxonomy of the course skills (See Appendix F for sample taxonomy), it is to be used in tagging all the problems and resources like videos and reading material in the course.

For this project experimentation and prototyping of the machine learning pipeline, tagging was not done at skill level but at problem level. In our AE experiment dataset we tagged each problem and each unique url with a distinct tag, meaning the skill dictionary consisted of all unique problems and urls. Tags from 1 to 336 represented problem events and tags from 336 to 627 represented unique non-problem events.

This tagged event stream data set is then used to retrieve model specific data format in each case, this is explained in detail in the next section. In our experiment we have divided all the data into two sets: training data and the test data such that test data represents same users in all our model experiments. This was done to standardise the test data results across different models.

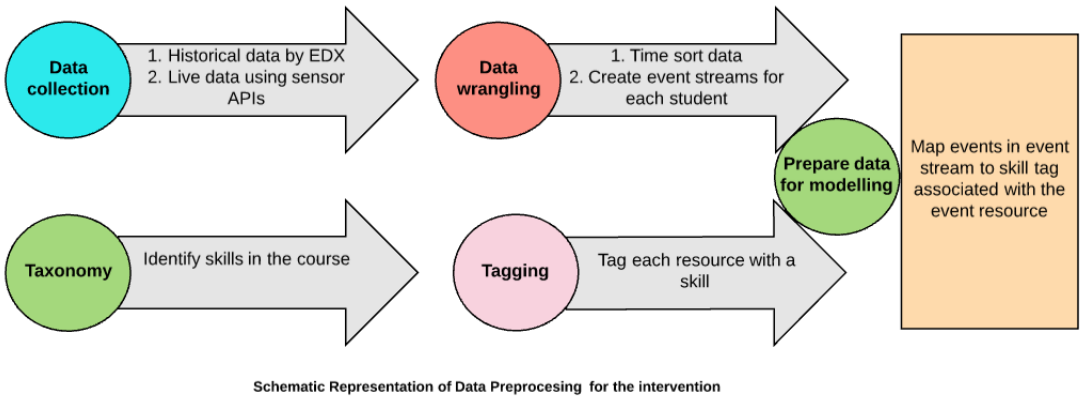


Figure 12: Schematic Representation of Data Preprocessing

4.4.3 Model Architecture

We use machine learning models for two items in our intervention. The first item is the prediction of knowledge levels using DKT (Deep Knowledge Tracing) and the second is the resource recommendations to fill knowledge gaps. For both models we have proposed to use Recurrent Neural Network (RNN) with long short term memory (LSTM).

Brief Introduction of RNNs: [12] RNNs are neural networks which allow signal transfer in two directions. Unlike feed forward neural net where the signal output flows in only one direction from one layer to the next, in RNN, the output signal from a layer is send to next layer as well as fed back into the same layer giving them ability to operate with sequences. This essentially creates a model that is able to learn the context in sequences of the input data. The bidirectionality of signals in RNN, however, makes it extremely difficult to train. Since these nets use backpropagation, we run into the problem of vanishing gradient and it prevents the model from learning long term dependencies. This leads to exponentially small gradients and a decay of information through time. In order to address the problem, gating of RNNs is used. Gating is a technique that helps the net decide when to forget the current input, and when to remember it for future time steps. We have used LSTM gating on our models. LSTMs or the Long Short Term Memory layer has switches, it can bypass not so useful units and thus remember information for longer time steps.

DKT (Deep Knowledge Tracing): We are using LSTM RNNs for knowledge tracing. In DKT, given the past performance or behavior of a student we want to predict his/her probability of knowledge level in different skills. In the MOOCs context, our hypothesis is that there exists a significant relationship between student activity on the MOOCs platform in a course and his/her knowledge levels in different skills taught in the course. So, our Deep Knowledge Tracing model is a RNN that uses the student event stream to predict the student's knowledge level in the course skills.

Our experimentation was divided into two phases. These are explained in detail below:

4.4.3.1 Phase 1

In the first phase, we wanted to test the relationship between the performance of a student and his knowledge level in different skills taught in the course. Here we have used a recurrent neural network with a LSTM layer. It takes as input the event streams of students and outputs the probabilities of knowledge level in different skills of the course at the next timestep. Event streams of each student in phase-1 consist of problem events only. The labels in training data are the response streams i.e it represents the correctness of response of each problem event, 0 being incorrect and 1 being correct. We have used 100 timesteps of sequence length in our model.
The input is fed as one hot encoded problem-event stream of 100 timesteps for each student. Size of one hot encode vector of each event was equal to the number of unique problem events in the DELFT AE course.

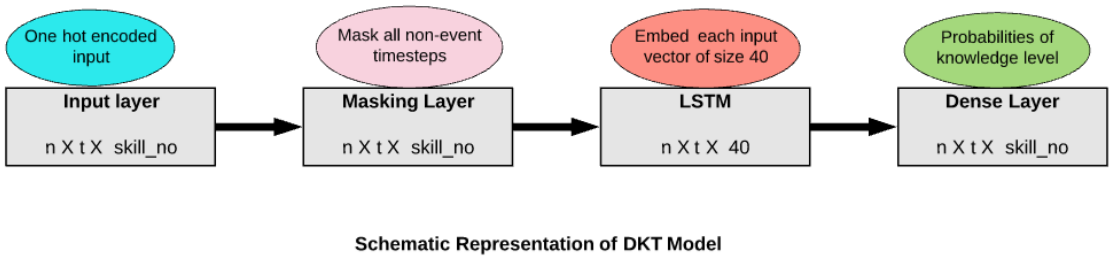


Figure 13: Schematic Representation of DKT Model

4.4.3.2 Phase 2

In the second phase, we wanted to test the relationship between the performance as well as the behavior of a student with his/her knowledge level in different skills taught in the course. The RNN structure for this phase was the same as used in phase 1 above. However the input to the model changed. The events in event stream included all types of the events a student can perform in the course like watching a video, reading a lecture, attempting a quiz etc. Size of one hot encoded vector of each event was equal to the number of unique events in the DELFT AE course dataset. The input is fed as one hot encoded event stream of 100 timesteps for each student, so that the number of input timesteps in both the models remains the same.
The labels in training data are the response streams i.e it represents the correctness of response of each problem event, 0 being incorrect and 1 being correct and for non-problem events the response is always 0.

4.4.3.3 Phase 3

The proposed phase 3 of the research planned to look at the co-operative working of DKT from phase 2 with the behavioural Modelling [11]. The idea is that we train two models with shared layers one for DKT output and the other one for the Behavioral output. Based

on the knowledge level from DKT output we get the skills of low mastery for a student and from behavioral model output we get the possible actions of that student. Once we know these skills we can identify the relevant resources for that skill in the course. In order to increase the probability of student to work on the suggested resources, the possible resources can be taken from the high probability action likely to be taken by that student. The idea is to make the suggested corrective feedback more natural and effective by providing it at the right time. This phase was however not completed in this project research and is a promising future work.

4.4.3.4 Comparison of Performance

The DKT model performance was measured in terms of accuracy of correctness of question at a timestep and the predicted probability of that question in that time-step by the models. We had divided the data into training data and the test data. Training data comprised of 8242 distinct students with 100 timesteps of event streams. Test data comprised of 1000 distinct students with 100 timesteps of event streams. Both these data sets were the same for phase 1 as well as phase 2. Figure below shows the model loss during training for DKT phase 1 and phase 2 for 5 epochs.

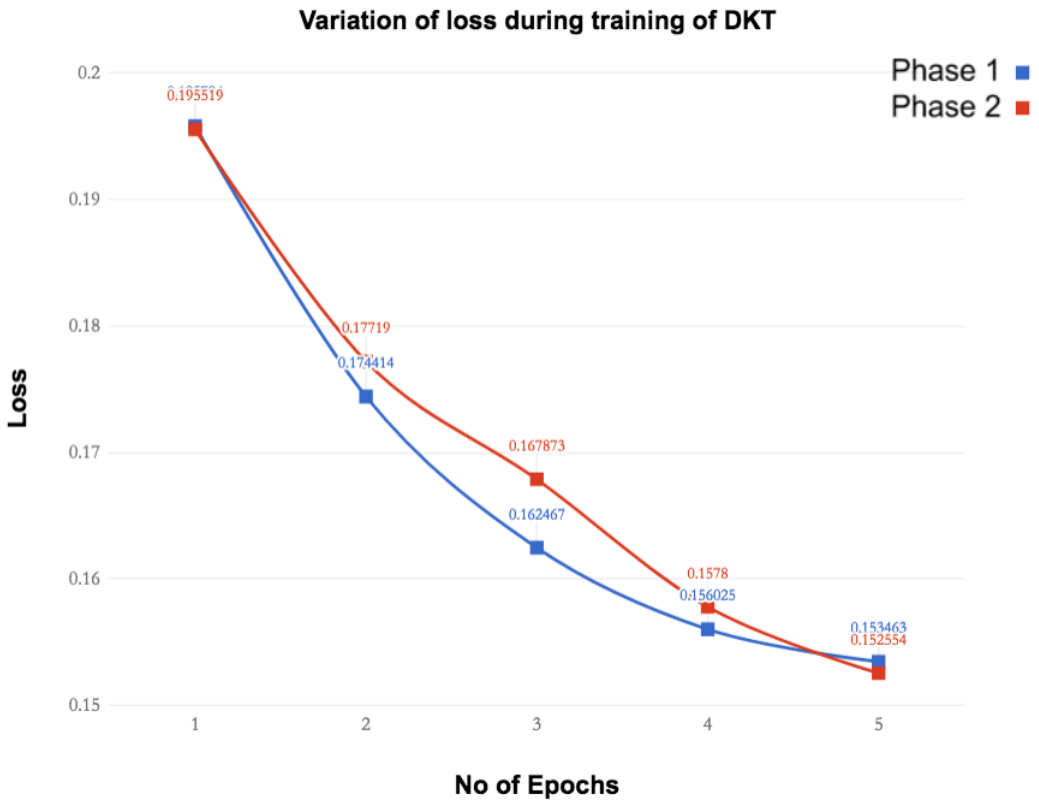


Figure 14: Training loss for DKT models

To evaluate the efficacy of RNNs in our data we also established baseline accuracies. Baseline metrics were also calculated on the same datasets. We used two different types of baselines. For the first baseline, we picked the majority class label among all students for all questions and applied that label for the whole test set. With this approach, we observed an accuracy of 0.848 on our test set. For the second baseline, we identified the majority class label for every question in the training set and propagated these labels correspondingly to the test set. This approach yielded an accuracy of 0.898 on the test set.

Our phase 1 and phase 2 models which were trained for 5 epochs using batch gradient descent achieved the following performance metrics:

Model	Training Data Accuracy	Test Data Accuracy
Baseline 1	NA	0.848
Baseline 2	NA	0.898
Phase 1	0.922801	0.9211
Phase 2	0.922873	0.9219

Model	Training Data Recall	Test Data Recall
Phase 1	0.613261	0.5938
Phase 2	0.597795	0.5937

Model	Training Data Precision	Test Data Precision
Phase 1	0.6278	0.6243
Phase 2	0.6159	0.6363

Model	Training Data Loss after last epoch of training	Test Data Loss
Phase 1	0.1534	0.1532
Phase 2	0.1525	0.1525

Table 5: Metrics Achieved in DKT models

4.4.4 Discussion on Results and Future Work

From the performance results above we conclude that DKT models do better than just guessing the majority class. However the performance of phase 1 and phase 2 DKT was very close. We were able to observe the decreasing loss of models in both phases, indicating model learning. While we were able to establish the working of RNN based DKT model in MOOCs data, we are not able to conclude that hybrid DKT model which uses behavior and assessment of a student on the platform can perform significantly better than assessment based DKT only. We believe that in the future if we include the information on time spent on different behavior verticals by a student, we might be able to train a more naturally

behaving DKT which assigns knowledge levels on the basis of assessments as well as time spent on various resources in the course. In the future we can also experiment with CNN based Neural Networks to capture similarity in localized streams events than over entire length of student behavior. We can also explore attention models - Hierarchical neural attention in both phases of DKT to reduce the training cost in otherwise fully connected Neural net used in this research. As indicated earlier, Phase-3 is also a very important next step, which studies the combination of RNN for Knowledge tracing and behavioral modelling to aid in providing corrective feedback to students on MOOCs.

5 Product

5.1 Infrastructure

Feedback from usability tests were incorporated into a review page as a final product. This review page was created using HTML and Javascript. This html page reads the following data files:

1. Modules.json - JSON file containing the information about the course like the chapters, sections, subsections and each student's activities like resources visited/skipped by a student to show the student's course progress.

2. Percent.csv - Csv file containing the output from the model with information on a student's mastery level, average mastery level of the students in the current offering of the course, associated skill id and the percentage of resources viewed by the student for each skill in the course. s

3. Skill_link.json - JSON file containing the suggested resources in the course as outputted by the model and the associated skill id.

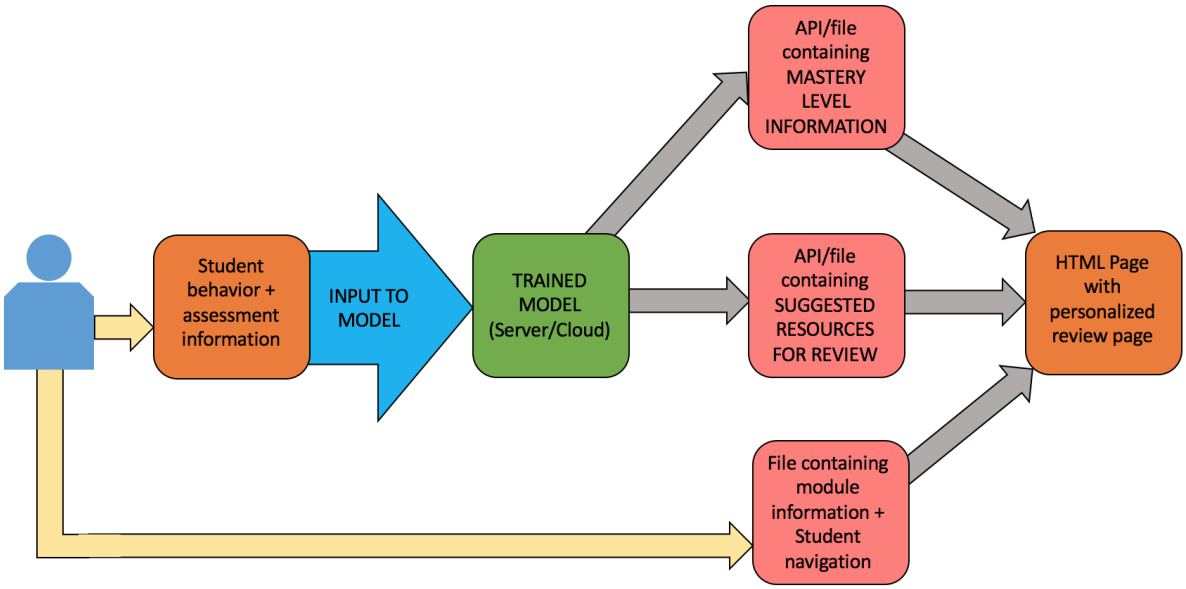
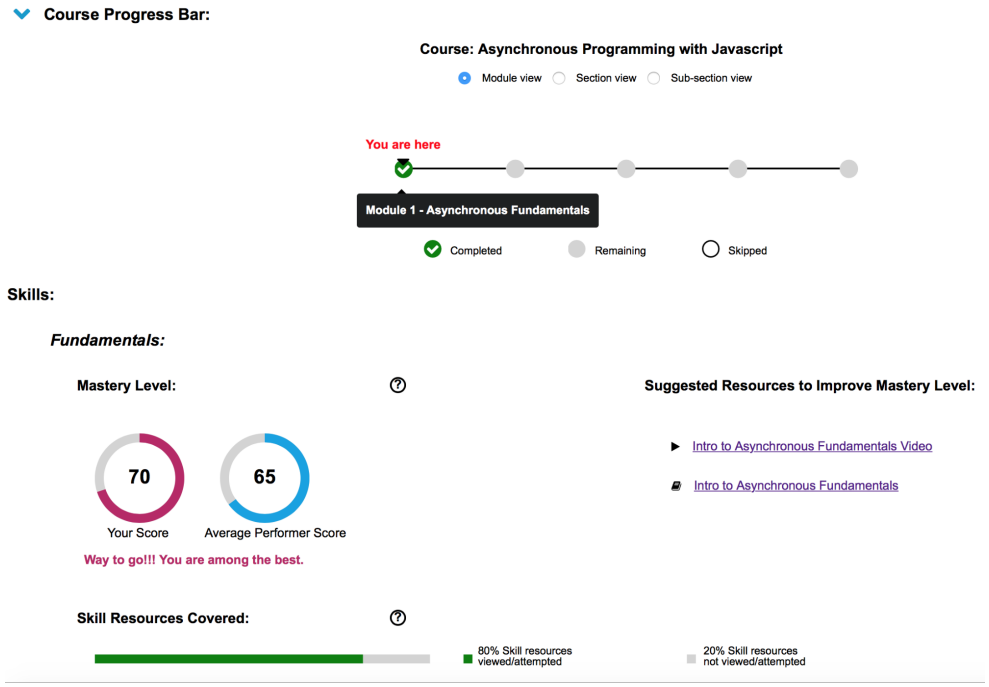


Figure 15: Infrastructure for html page integration with the MOOCs platform

The HTML page uses the modules.json file to display 'Course Progress Bar' which gives information on the course progress and which part of the course the student is currently on. This would give the student an overview of what he/she has completed and what is remaining in the course. The HTML reads Percent.csv and skill_link.json to display 'Skill Mastery Level' and 'Average Performer Score' in the review page to show information on how the student is performing in the course as well as how the overall class is performing. It also shows how much of the resources in the course associated with a particular skill has been viewed by the student. Percent.csv and skill_link.json are dynamic files which would be generated by the trained model at the end of an assessment. The html page also has placeholders to display information on suggested resources to review as outputted from the proposed phase 3 model to assist students in revisiting concepts to improving their mastery level in that skill.

To keep track of the student's activities, javascript sensors can be embedded in each page of the course and the activities can be logged from the client side for each student which can then be stored in a database and used as input for the model. The trained model for the particular course can be stored in the server and the information containing the student activities can be directed as input to the model. The output from the model can be posted as a json/csv to an api, which can be read by the HTML page. This output is the personalized suggestion and mastery level for that particular student based on his/her behavior and assessment scores. Client side senor code and model integration has been previously implemented by Pardos et al. [11] in an edX course to show resources that the student should next visit based on their behavior alone.

5.2 Product Snapshots



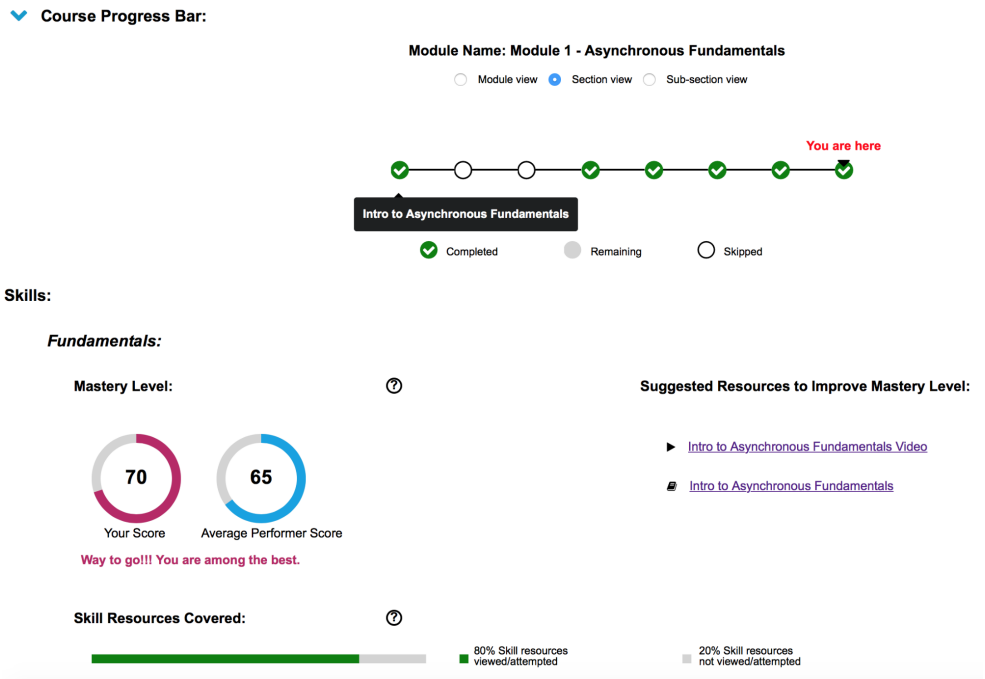


Figure 16: Software prototype of Final Html Page Design showing different views

5.3 Future Work

The future work on this project could involve implementing client side sensor codes to log student information and model integration in the back-end which would then dynamically output personalized review page based on a student's performance and behavior patterns. A/B testing can then be done on a control group and a treatment group with the treatment group being shown the personalized review page and the impact of the treatment on the group can be measured to determine if there is an decrease in dropout rates and also to determine if there is student engagement on the suggested resources after the suggestion has been shown. If user engagement has increased on the suggested resources with low bounce rate, then the suggested resources and motivating messages could have been useful to the student.

6 Conclusion

This project was useful in uncovering the user behaviour and motivations on MOOCs platforms. We sought insights into what user's considered motivating or demotivating on these platforms, to understand the possible causes of dropout. While many causes for dropout surfaced in the user research such as lack of time, lack of feedback, isolation and the feeling of getting lost, we focussed to address the problem of unavailability of adequate feedback on MOOCs platforms. We analysed our findings from the cognitive theory perspective and realised that a pedagogical feedback system can be useful in motivating users to complete

the courses. We designed a review page to provide information on user knowledge levels, relative performance and course progress. To create an automatic scalable feedback system we experimented with RNN based Knowledge tracing models. While our Review page was found useful during usability tests, users found that the infographics were not intuitive. With respect to our DKT model, we were able to achieve around 90% accuracy but the increase in accuracy was not significant enough in our phase 2 model to recommend to EdX to use RNN based DKT to display analytics in the designed Review page.
This project has made two major contributions. First, the experiment with DKT has shown a moderate increase in accuracy over naive baseline method. Therefore, we believe our work has set a stage for further exploration to improve accuracies by increasing model complexity and also investigating the motivational effect of "psychological framing" on student. Second, we have laid down a detailed user study on the need to provide personalized learning environment to MOOCs users.

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References

[1] Benjamin S. Bloom. The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, 13(6):4–16, 1984.

[2] Chen Zhenghao, Brandon Alcorn, Gayle Christensen, Nicholas Eriksson, Daphne Koller, and Ezekiel J. Emanuel. Who's benefiting from moocs, and why. `https://hbr.org/2015/09/whos-benefiting-from-moocs-and-why`. Accessed: 2018-04-30.

[3] The future of online learning. `https://www.ft.com/content/f8a03bbe-9802-11e4-b4be-00144feabdc0`. Accessed: 2018-04-30.

[4] René F Kizilcec, Andrew J Saltarelli, Justin Reich, and Geoffrey L Cohen. Closing global achievement gaps in moocs. *Science*, 355(6322):251–252, 2017.

[5] Ashton Anderson, Daniel Huttenlocher, Jon Kleinberg, and Jure Leskovec. Engaging with massive online courses. In *Proceedings of the 23rd International Conference on World Wide Web*, WWW '14, pages 687–698, New York, NY, USA, 2014. ACM.

[6] Product review : Edx. https://www.pcmag.com/article2/0,2817,2484806,00.asp. Accessed: 2018-04-30.

[7] J.G. Greeno, A.M. Collins, and Lauren Resnick. Cognition and learning. *New York: Simon Shuster MacMillan*, pages 15–46, 01 1996.

[8] Albert Corbett. Cognitive computer tutors: Solving the two-sigma problem. In Mathias Bauer, Piotr J. Gmytrasiewicz, and Julita Vassileva, editors, *User Modeling 2001*, pages 137–147, Berlin, Heidelberg, 2001. Springer Berlin Heidelberg.

[9] Mastery learning: An effective teaching strategy. http://www.nyu.edu/classes/keefer/waoe/motamediv.htm. Accessed: 2018-04-30.

[10] Chris Piech, Jonathan Bassen, Jonathan Huang, Surya Ganguli, Mehran Sahami, Leonidas J Guibas, and Jascha Sohl-Dickstein. Deep knowledge tracing. In C. Cortes, N. D. Lawrence, D. D. Lee, M. Sugiyama, and R. Garnett, editors, *Advances in Neural Information Processing Systems 28*, pages 505–513. Curran Associates, Inc., 2015.

[11] Zachary A. Pardos, Steven Tang, Daniel Davis, and Christopher Vu Le. Enabling real-time adaptivity in moocs with a personalized next-step recommendation framework. In *Proceedings of the Fourth (2017) ACM Conference on Learning @ Scale*, L@S '17, pages 23–32, New York, NY, USA, 2017. ACM.

[12] Understanding lstm networks. http://colah.github.io/posts/2015-08-Understanding-LSTMs/. Accessed: 2018-04-30.

Appendices

A Pre Survey Questions

1. How many online courses are you currently enrolled in or have enrolled in the past?
2. Why did you not pursue an online course?
3. What was the subject matter of the courses you have taken?
4. Which platforms have you used?
5. How long have you been using these platforms?
6. Why did you choose to take an online course?
7. If you have completed any course, what was your motivation to complete it?
8. If you did not complete any course, what prevented you from completing it?
9. How will you rate your overall experience with the online courses?
10. How do you think online learning experience can be improved?
11. What is your country of residence?
12. How old are you?
13. What is your current employment status?
14. What is the highest education you are pursuing/ have completed?
15. How many years of work experience do you have?
16. If you have additional thoughts that you would like to share about your online learning experience, please provide us with your email address.

B Preliminary Interview Questions

1. **Intro**:

   Welcome lines:

   Thank you for coming in today. I understand that you have used technology before to learn new concepts and how technology can be used to improve the learning process, we will spend the next 30 mins going over that. If you don't mind – I would like to record our interview, hope it's ok with you. Please let me know if it makes you uncomfortable.

2. **Warm-up**:

   Can you talk about your process of learning a new concept or a topic on your own? How much time do you spend in learning topics on your own?

3. **Focus**:

   What are some technologies or platforms you use to learn new or unfamiliar concepts or topics on your own? Do you prefer to use certain technologies more than the other?

4. **Deep focus**:

   What helps you to understand a concept or a topic really well? What are some of the problems you face when you are trying to learn something new using technology?

5. **Retrospective**:

   Is there any other thing you would like to add? Summarize

6. **Wrap-up**:

   Mention that the interview is now at close. feel free to ask any questions

C In-depth Interview

Interview guide

Introduce yourself.

Brief description of the project: "Thank you for doing this interview. We are trying to build gauge how you have used MOOCs or online learning course in the past to better understand pain points in the learning process."

Interview questions.

Warm up: (5 min)

- What is your highest education?
- Have you taken a MOOCs course?
- When was the last time you took a MOOCs course?
- How many courses have you completed?
- Can you talk about your process of learning a new concept or a topic on your own through a MOOCs?

Focus: (10 min)

- What do you think causes a drop in motivation to complete the course?
- What are some factors that keep you motivated to pursue a course?
- In your experience, how does MOOCS make learning an easy process?
- In your experience, how does MOOCs make learning a hard process?
- How do you evaluate your learning in a course?

Deep Focus: (10 min)

- Describe the last time you had to use moocs to understand a new or a difficult topic?
- What is the most time consuming process when going through a course?
- What are some reasons you felt the need to revisit topics?
- What do you do after you are done with quizzes or assessment?
- Describe the last time you felt you were stuck in a course?

- What do you do if you get a question wrong?
- Have you felt the need to know how others have performed on the course?
- Describe your process to find the resources within the course for the questions you got wrong?

Wrap up: (5 min)

- How do you think online learning experience can be improved?
- Is there anything else you would like to add?

Extra questions:

- How much time do you spend learning topics on your own through MOOCs?
- What made you choose a MOOC over any other learning method ?

In-depth Interview Responses:

Description of user 1:

Our first user has completed a Masters degree in Computer Science and is now working fulltime as a professional. He has completed a few courses from Coursera, Udacity and has browsed through EdX videos without ever completing a course on EdX. The last time he took a course using MOOCs is about a year back.

Question: What is your learning process?
Response: The user usually would first spend some time to search and find a course that is relevant to the topic he is interested in learning. After finding one, he would quickly go through the chapters to get a sense of what the course has to offer. This process would also involve skimming through the introduction and background as fast as possible as they tend to be less rigorous. He mentioned that he would do the assignments more carefully as they were the most important part of understanding the content of the course in his opinion.

Question: How much time do you spend on any topic?
Response: The user felt the time taken would vary and depend majorly on the topic, which at different instances command different levels of commitment. In practice, he would try to work on the material over a weekend and spend 4-5 hours at a stretch and try to wrap up in 3 to 4 such sessions.

Question: What is your goal in the course?
Response: The user answered this question illustrating an example scenario. If the user wants to learn spark and the course has a lot of segments on introduction to familiarize the concepts that are already known to the user, he would try to skip over them. He would

quickly go to the chapter that is directly connected to his topic of interest.

Question: What makes you choose MOOCs over other channels of online learning?
Response: The user explained how he would have to spend less effort with MOOCs as someone is explaining the material in the videos. In contrast, if he has to use some resource available on the web, he has to first find a credible source to follow and then go through it in order to understand on his own. This whole process requires more effort to ensure that the user understood what was intended from the course. He was also concerned whether what he understood is correct and sufficient as there is no mechanism to confirm the same.

Question: What is your process of validation
Response: The user usually relied on quizzes and programming assignments to validate his understanding.

Question: How does MOOCs make online learning experience better?
Response: The user felt that through MOOCs he can take any course of a university without having to enroll in one. It is easily accessible and also available to broader audience. He mentioned the structure is at times time consuming, explaining that some courses in the beginning require him to go through parts that he already knew. Also, the act of watching videos take more time as opposed to reading a research paper.

Question: Can you think of reasons when you had to revisit certain lectures/videos?
Response: The user explained that because he skips through videos and course content, at times he needs to refer back.

Question: What do you do after you finish a quiz? **Response:** The user would act depending on his performance in the quiz. If he did well he would move to the next section. If not, he would look at which questions he got wrong and try to find why.

Question: What do you do when you felt stuck?
Response: The user felt that in a MOOCs setting, it is hard to be "stuck" at a point. He further explained his rationale saying that there was nothing stopping a learner from moving ahead to the next section or simply abandoning.

Question: Have you ever felt the need to know how others are performing?
Response: The user never felt this need.

Description of user 2:

Our second user has completed a Masters degree in Biomedical Engineering. She has completed many courses on MOOCs and is an avid learner using online courses.

Question: What keeps you motivated in continuing?

Response: The user does not like the courses which are more heavy on presentations and she is not able to interact much with the professor or see him in the videos. If the course has an engaging professor and well structured assignments it keeps her motivated.

Question: Do you think MOOCs has made the learning process easy?
Response: The user felt MOOCs have made the learning process really easy. She explained that MOOCs can be easily accessible by everyone illustrating that even for people who are working full time, MOOCs have made it really easy as they can take it at night since the content is available at all times. She then goes on to describe how MOOCs can be bad at times as there is no pressure on the learner to complete the assignment. She stresses the importance of pressure and deadlines while learning and feels that sometimes paid courses help you to work hard as there is that element of pressure involved. She quickly clarifies that this should not be taken as a general rule and she did not want to indicate that paid course are the best way to learn as she herself has successfully managed to complete many courses in spite of simply auditing it. She further adds she would like it more if there was a deadline in completing a course as she thought it would motivate her more to finish it.

Question: Do you think knowing how others are performing in the course and competing with them would motivate you more?
Response: The user does not think knowing others' scores can be useful in her case. She goes on to explain how this feature might not add value because she feels that if we don't know the person there is no point in competition. She felt her own own performance served as motivation to continue in a course. Furthermore, in her opinion she could just look at her score and infer whether she is doing well or not so there was no point in comparing it with others unless they are your friends or someone whom you know.

Question: What is the importance of a teacher in your learning process?
Response: The user thought it is "super-important". She outlines how a teacher with good communication skills and one who is very engaging can help a learner stay motivated. In contrast, she disliked the professors whose mode of teaching was less interactive and focussed on simply reading out material presented in the form of slides. She expressed how looking at the professor talking in the video can be engaging and can make the process of learning less boring. The user said she has encountered some courses where the professors just read pre-prepared material and how that makes her less enthusiastic and she struggles to continue. Overall she highlighted that the personality of a teacher should be talkative and underscored the importance of engagement several times. Moreover the role of teacher in keeping students motivated is critical when a learner is not doing very well.

Question: Comparing the MOOCs and a traditional class what is that one thing that you will miss in online course?
Response: The user thought the time at which clarification is seeked and provided is the major difference between the two modes of learning. She explained how in an online

setting when she doesn't understand something she can't ask a question to the professor and ask for clarification midway whereas she could easily do that in a classroom setting. The user again highlighted the importance of receiving timely "feedback" in the classroom setting.

Question: Did you ever encounter a situation when you thought you fully understood a concept but struggled while applying it?
Response: The user said it happened to her quite often. Usually when she would freshly learn something and apply it on the assignments, she would remember everything but over time it would fade and hence when doing a real world problem later she would need to revisit certain topics.

Question: How would you value a system that takes into account, your behavior along with performance in quizzes and evaluates your learning in a skill?
Response: She found the idea exciting but suggested that she would not take the results of such a system too seriously

Question: How online learning can be improved?
Response: She stressed a few salient features that can make online learning more helpful. Few of the things she mentioned were well structured assignments, interactive professors, having summary at the end of every lecture, end of course quiz etc. Along with that, having active study boards, TA/mentor to explain assignment are somethings which she thought can prove to be very helpful for someone who doesn't have a background in that field.

Description of user 3:

Our third user has completed a Masters degree in Computer Science and now working fulltime as a professional. This user has completed approx. 15 courses on MOOCs. These included both short(2-5 hours) and longer(4-6 weeks) courses. The last time she took a MOOCs course was as recent as 2 months ago. The user talked about how she is more driven by curiosity to learn something new and exciting not just by study related learning and that is the primary reason why she takes many online courses.

Question: what motivated you to complete the courses you started?
Response: Most of the courses that the user had completed were of short duration and did not have a lot of quizzes or assignments. She mentioned that she did not like courses that were unnecessarily long or where the content has a lot of repetition in the form of mashups. She also tends to not like the courses that have a lot of quizzes or if the pace is too slow.

Question: How do you evaluate your learning?
Response: The user felt that she would continue to revisit the video unless she has fully

understood it. She would attempt to explain it to herself in simpler terms and if she is unable to do that it would be an indication that she hasn't fully grasped the concept. The user did not feel the need to take quizzes or assignments to test her understanding as she thought she would personally be able to judge that.

Question: Can you talk about your process of learning through MOOCs?
Response: The user described how she gets random spikes of interest in some topics and then she would binge watch the videos for 4 hours or more. She also said as she spends so much time on visual content or simply watching videos that was the reason why she prefers shorter courses over longer ones. If she ended up liking the course she would revisit it at a later time, she talks about how she would not do the revisiting actively but that will be something she might do some other time. In a case when she did not like the videos she would never revisit them later.

Question: What makes you not like a course?
Response: The user reiterated the same points which she had highlighted in earlier responses which were pace being too slow, too many quizzes/assignments etc. She brought up the activity of "binge watching" again which was something she did more if the content is interesting and it worked for her for a few hours.

Question: What do you do when you get a question wrong?
Response: The user said that she would spend some time and try to understand the reason why she got the question wrong and then will explore outside resources. The user also mentioned there are times when she wouldn't stress too much about it. The user said she would not prefer to revisit the video or material because she felt that it would not help her. She explained that if she already finished a topic, she would have already understood everything the video had to offer so there was no point in going back again.

D In-depth Survey Questions

1. How many moocs courses have you completed?
   - One
   - More than one
   - None
2. What is your age?
   - 18 years and above
   - $<$ 18 years
3. What is the highest or current level of education you have completed?
   - Have not graduated high school
   - High School Graduate
   - Bachelor Degree
   - Master's Degree
   - Professional/Academic Doctorate Degree
   - Other (Please Specify)
4. Which of the following best describes your current professional status?
   - Student
   - Working professional
   - Looking for job
   - Taking break from work.
   - Others: Please specify
5. How important are the following elements for you in a course?

	Not at all important	Slightly important	Moderately important	Important	Very important
Exercises, quizzes, assignment					
Videos					
Reading materials					
Forums					

6. How do you evaluate your learning in a course?
7. When do you choose to revisit topics or sections of the course? (Multiple choice)
    - When I don't understand a topic
    - If I get quizzes wrong
    - To reinforce understanding in parts of the topic
    - Never
    - Others: Please specify
8. What do you like to do if you get a question wrong?
    - Look at the answer
    - Revisit videos/lectures
    - Engage in discussion forums
    - Move on
    - I usually don't know what todo
    - Leave and not return to the course.
    - Leave and return to the material later
    - Others: Please specify
9. How difficult is it for you to find the resources within the course for the questions you got wrong?
    - Not at all
    - difficult
    - Slightly difficult
    - Moderately difficult
    - Difficult
    - Very difficult
10. How important is it for you to see how well you're doing in different topics of the course?
    - Not at all important
    - Slightly important
    - Moderately important
    - Important
    - Very important

11. How important is it for you to see how well you're doing in different topics of the course relative to other learners taking the course?
    - Not at all valuable
    - Slightly valuable
    - Moderately valuable
    - Valuable
    - Very valuable
12. What types of feedback do you value?
    - Not at all important
    - Slightly important
    - Moderately important
    - Important
    - Very important
    - Instructor or teaching assistant feedback
    - Comments on the pace of your progression through the course
    - Feedback on your performance in the course assessments
13. How do you think online learning success in MOOCs can be improved?

E Usability Testing Guide

Task 1:

- Take 5 minutes to familiarize yourself with the material or section.
- Attempt three questions.
- And then assume you are someone who has been going through this course religiously and want have got one of these questions wrong. Press the next button and can you describe what is going through your mind.
- What they will do next.
- What would you do improve your skill score.

Task 2:

- Find out how many topics you have skipped in the course until now.

Task 3:

- Imagine that you have completed a section on "Introduction to Formal Logic" in a course called "Logical and computational thinking" and you are shown this page after attempting a quiz on Factoring and you want to improve your skill score.

Task 4:

- Take 5 minutes to familiarize yourself with the material or section.
- Attempt three questions.
- And then assume you are someone who has been going through this course religiously and want have got one of these questions wrong. Press the next button and can you describe what is going through your mind.

Post-Usability Test Survey

- On a scale of 1 to 5 (1 being poor, 5 being excellent), how would you rate your experience?
- What are two things you found frustrating about the design of the website?
- What are two things you liked about the design of the website?
- Was there anything that surprised you or was unexpected while completing these tasks?
- Any final comments or feedback you'd like to tell us?

Usability Study Responses:

We conducted seven usability tests and below represents four usability tests that highlighted important findings.

User 1:

The user started by hovering around the course progress bar. He was able to identify that there were different view modes which could be selected through the buttons. He spent some time looking at what information was being conveyed by selecting the buttons individually and he found this information to be useful. He then scrolled down to look at the skill mastery score and his first impression was that he was pretty confused. He initially thought the score were in the form of percentage. He struggled a lot trying to understand what the remaining 30% indicated. He said it is not very clear whether these 30% was something he skipped from past sections or was it something that would be encountered in future. With the skill progress bar he did not pay attention to the legends and asked many clarifying questions about how the top score could be 85% when only 80% resources had been viewed. The user was expecting the score and progress to be on the same scale and was trying to read them together. In the end, he was able to understand that the percentage score was showing his own behavior and had nothing to do with the top scorers score. The user engaged in a discussion and was curious to find out how the scores were calibrated and calculated. When the interviewer probed him further about his interpretation of the values, he said that the 20% in the skill progress bar was something that is going to come in future failing to realise that it also accounted for the questions he had skipped. For the skill mastery score, looking at the 70%, he said that he could know that 30% was missing and that could come from 2 ends- one part from things he got wrong and the other from what would come in future. He had no clue what the distribution was just by looking at the plots. When the user was asked to suggest some improvements that can be made to the interface, he added that having 3 components in the skill progress bar - resources skipped, resources viewed, and resources yet to come could probably make it more useful. He completely missed the suggested resources links and noticed that only when it was brought to his attention. He found the feature to be beneficial and said that he would use it. He stated that this feature would save his time.

User 2:

The user liked the Course progress bar and also thought that this feature is something that could help her stay motivated. She was excited to see the green button and mentioned "in my subconscious I feel seeing this will encourage me to watch all videos and get all green ticks and fill all the holes". Regarding the level of granularity she said that she would prefer an overall progress instead of having subsection etc. It would be too much information and that would make the interface more messy. She did not feel skill mastery score was important. She felt that if she did not do good in a quiz she would redo the quiz or rewatch the lectures. She thought the score was calculated from quizzes and assignments. She did not find skill progress bar to be important.

User 3:

Regarding the course progress bar, the user said that it showed the status of how much was left, what was completed, and what was skipped. For the skill mastery score she said it represented the percentile score of each "thing". She kept using the term 'thing' a few times and then towards the end switched to using the term 'course' for the skill mastery score. For the skill journey, she guessed that if she completed the rest 20% that might be coming from the portions she had skipped and working through the skipped portions might improve her score. She inferred that the 20% was coming from the videos/materials she had skipped and couldn't figure out that it might be caused by something that she would encounter in future sections. When asked if she thought it was helpful, she described that progress bar is good to know as she could see how much was still left. The Score did not matter much to her. She also said that it might be helpful to others but not to her. She described herself as not falling under that user group for whom it would be helpful. She was not able to find the suggested links section. When it was brought to her attention, she thought that those were course titles. She clarified that she doesn't tend to visit or click these links to resources. According to her, it's easier to search something on Google which she supported by saying that some people might prefer these links but she would not go to these suggested resources as they were not directly implied. In her words, something similar to "hey you could see this video to solve this question" would have caught her attention and would have prompted her to click on them.

User 4:

After describing the scenario, the user was shown the review page and asked to look at this page and process all the information contained in that page. She tried to browse up and down a couple of times. She correctly identified the progress bar and described this bar would show her what point in the course she was at that instance of time and what topics she had missed. She was able to figure out that there were multiple granularities at which she could view the course progress and mentioned while viewing the subsection view that she did not have any subsection remaining. The different view modes were confusing to her but she liked looking at the course progress bar as a whole. Then she moved on to look at the skill mastery score. She started reading the comment that said "You are among the best" and was ecstatic to see her 'good' score. She saw the highest score was 85 and her score was 70 and she commented "I am not among the best but it still says you are among the best". She also added since the score information was represented in a circle, it should be showing the score as a percentage. With regards to skill progress bar, she was unsure what the score signified. She initially thought that those were resources she viewed but then she quickly clarified that it might be the quizzes she had attempted. So she found the word "skill resources" to be misleading and couldn't quite understand what it meant in that context. She further explained that the confusing element with skill resources was whether it referred to the resources that she could use to test her skill or the resources that she could use to gain that skill. When asked specifically about the different parts of the review page that she found helpful, she said that she would not have paid too much attention to course progress bar and would have skipped it because she thought she would

already have that information. “When I skipped a video I would know that I skipped it”. Skill Mastery score was also not of value to her as she personally did not care too much about score and how it compared to others. She said that it might be a nice to have feature for some users but she would not care about the information that is displayed there. She did find the suggested resources links to be a useful feature and also said that it was the only part in this entire page that she would actually pay attention to.

F Sample Taxonomy

Sample Taxonomy for Deep Knowledge Tracing.
Course Name: Logic and Computational thinking
Platform: Edx
Red indicates the skill and Blue indicates the skill tags for the assessment questions.

- Section - Formal Logic and Computer Science
  - What is logic and critical thinking
    - Logic, Critical Thinking, and Computer Science
  - How computers work
    - What is a Turing machine?
    - Bits and bytes
    - Algorithms
  - Program to logic conversion
    - Logic and computer science
  - Bonus: interviews - video
- Section - Introduction to Formal Logic - (Logical analysis)
  - Logic
    - Introducing logic - video
    - An introduction to logic
  - Arguments
    - Introducing arguments - video
    - Arguments
  - Statements
    - Introducing statements - video
    - Introduction to logic: statements
    - Introduction to logic: More on statements
  - Propositions
    -
    - Introducing Propositions - video
    - Introduction to logic: Propositions
    - Introduction to logic: More on Propositions
  - Truth value

    - Introducing Truth value - video
    - Introduction to logic: truth value
  - Section summary

- Quiz:

  1. Which three of the following are parts of an argument? (choose 3)
     Tag: Arguments
  2. Examine this argument:
     Premise 1: All programmers are coders
     Premise 2: All coders are math specialists
     Therefore, Which one of the following statements would most likely be the conclusion of this
     Tag: Arguments
  3. Which two of the following statements could represent the proposition: All your data is in the cloud (choose 2)
     Tag: Proposition
  4. Which three of the following could be a statement in logic? (choose 3)
     Tag: Statements
  5. Consider the following argument:
     Premise 1: If the dog has fleas, the dog scratches itself
     Premise 2:
     Conclusion: Therefore, the dog scratches itself
     Which of the following would be the most likely second proposition to complete the argument?
     Tag: Arguments, Proposition
  6. The following is not an argument.
     Premise 1: If Tuesday is bagel day, then I will eat a bagel tomorrow
     Premise 2: Wednesday is taco day
     Conclusion: Therefore, I will have pizza
     What is it missing?
     Tag: Arguments, Statements, Proposition

- Section - Symbolization and Logical operators

  - Symbolization
    - Introducing Symbolization - video
    - Symbolizing Deductive Arguments
  - Operators
    - Introducing Operators - video
    - Introduction to Operators

    - Monadic and Dyadic operators
    - The Negation Operator
    - Conjunction
    - Disjunction
    - Conditional Operator
    - Necessary and Sufficient conditions
    - The Magical Conditional Statement - video
    - Sidebar: Operator of the Largest Scope
  - Truth table - deductive syllogism
    - Constructing a Truth Table for a Deductive Syllogism - video

- Quiz:

  1. Examine the following statement:
     If it is not the case that JavaScript is type safe and JavaScript is interpreted, then programmers should be extra careful or they should use a different language.
     How many operators are used in the statement above?
     Tag: Operators
  2. Examine the following statement:
     Either the fountain needs water, or my eyes are deceiving me and I need glasses
     Which of the following is the proper symbolization of that statement?
     Tag: Symbolization, Operators
  3. Examine the following statement:
     If golf is a long walk ruined then soccer is a short run enjoyed or, all sports are hard
     Which of the following is the proper symbolization of that statement?
     Tag: Symbolization, Operators
  4. Examine the following statement:
     If pepper is a spice and butter is a fat, then either this dish is too spicy or it needs more butter and then it will be perfect.
     How many simple statements are in the compound statement above?
     Tag: Operators
  5. Examine this statement:
     Either we're all going to the concert or, if Bob is sick then Susan will stay home and Chris and Maria will go.
     Which of the following is the proper symbolization of the statement?
     Tag: Symbolization, Operators