Original Paper

Abrar Alturkistani¹, Azeem Majeed², Josip Car¹, David Brindley³, Glenn Wells³, Edward Meinert¹,⁴*

¹Global eHealth Unit, Department of Public Health and Primary Care, School of Public Health, Imperial College London, W6 8RP London, United Kingdom
²Department of Public Health and Primary Care, School of Public Health, Imperial College London, W6 8RP London, United Kingdom
³Oxford Academic Health Science Centre, OX4 4GA Oxford, United Kingdom
⁴Department of Paediatrics, University of Oxford, OX3 9DU Oxford, United Kingdom

Corresponding Author:
Edward Meinert, BA MSc MBA MPA CEng FBCS FCMI
Department of Paediatrics,
University of Oxford, OX3 9DU
Oxford,
United Kingdom
Phone: +44 782 444 6808
Email: e.meinert14@imperial.ac.uk edward.meinert@paediatrics.ox.ac.uk

An evaluation of a Massive Open Online Course (MOOC) about data science for continuing education in healthcare
Abstract

Background: Evaluation of Massive Open Online Courses (MOOCs) is a necessary practice for appraising their application and analyzing their performance and benefits. Imperial College London in collaboration with Health iQ offered a 5-week MOOC Data Science Essentials: Real World Evidence.

Objective: This study was conducted to evaluate the MOOC: Data Science Essentials: Real World Evidence, concerning its impact on learners’ knowledge, skills and attitudes and on the use of data science in healthcare. The aim of the evaluation was to investigate the success of the MOOC’s objectives regarding ‘reach’ about intended audience and social networks, ‘efficacy’ about knowledge/skill gain skill and attrition, and adoption and sustainability of social networks for continual learning in this emerging field.

Methods: The study design was a mixed-method evaluation drawing on semi-structured interviews of 2 learners transcribed and analysed using Braun and Clark's method for thematic coding. A Kirkpatrick evaluation was completed on two interview participants who could be assessed at all four levels of evaluation.

Results: While the MOOC improved learners' knowledge of the topic, it could be improved regarding increasing communication and networking between learners. Participants reported increased knowledge but no change in skills and attitudes in the workplace after taking the MOOC. Lack of resources in the workplace and the change to a different workplace, which changed participant's responsibilities were barriers identified by not experiencing a change in skills and attitudes as a result of taking the MOOC.

Conclusions: The are two reasons that may explain why the MOOC while improving participants’ learning, was not able to change participants’ attitudes and use of data science in the workplace. Since the MOOC offered was about a brand-new topic (Real World Evidence) that requires the availability of specific resources, participants were not able to apply the
learning since these resources were still not available in the workplace. Also, having a job that
requires a different set of skills than the ones taught in the MOOC was another reason that
prevented a participant from applying the learning from the MOOC. Understanding the MOOC
learners’ experience, learning level and influence on behaviour change can potentially improve
future MOOCs to become more effective for learning and changing behaviour.

**Trial Registration:** The evaluation received ethical approval from the Imperial College
Education Ethics Review Process (EERP).

**Keywords:** Massive Open Online Course (MOOC), Online learning, Qualitative analysis,
Kirkpatrick Evaluation, Evaluation.

continuing education; e-learning; MOOC; Massive Open Online Course; education, medical;
education, medical, computer-assisted instruction; education, medical; medical informatics
applications
Introduction:

A Massive Open Online Course (MOOC) is a form of online learning, which became internationally popular since 2011 when a MOOC offered by Stanford University attracted a global audience from more than 190 different countries [1]. MOOC evaluations can help analyse its effectiveness and improve its application [2]. Also, although most MOOCs have free access for anybody interested, some MOOCs can offer to learn on highly technical topics and may require some background knowledge for the learner to understand the content, making it necessary to evaluate what population joined the course. MOOCs communication and networking features should also be assessed as findings from a case study reported that such activities in a MOOC could aid in "peer-supported learning" [3]. For these reasons, when evaluating a MOOC, it is essential to take into account aspects of the MOOC reaching its target audience, improving learning and skills and increasing opportunities for communication and networking.

There is a significant demand for trained data scientists [4]. The healthcare sector presents immense challenges where data science could impact key problems and is an area where it is underutilized and has massive potential to improve delivery of healthcare and patient outcomes by increasing efficiency and effectiveness. For example, using big data methods on the vast quantity of real world data could provide researchers with the ability to create predictive models which can identify who is at risk of developing a disease, and to create preventive and personalised care for patients through mobile phone applications [5].

The MOOC Data Science Essentials: Real World Evidence was offered by Imperial College and Health iQ with the aim to introduce learners to the concept of Real World Evidence (RWE) and inspire the application of these methods across various healthcare and life sciences industries
The target audience of the course was described as: "undergraduate student in data science, an analyst or commercial manager working in life sciences pharmaceuticals, healthcare regulation, biotech and medical devices, especially those “with an interest in the application of Information and Communication Technologies (ICT) within healthcare” [6]. Therefore it was crucial to investigate the success of the MOOC’s objectives regarding ‘reach’ about intended audience and social networks, ‘efficacy’ about knowledge/skill gain skill and attrition, and adoption and sustainability of social networks for continual learning in this emerging field.

Therefore, our main research question was: How has the course impacted the learners’ knowledge, skills and attitudes on the use of data science in healthcare? Moreover, our specific research questions were: what evidence is there that the intended target audience was reached? What evidence is there that the MOOC has made a difference to participants in their work or studies? What evidence is there of participant networks for data science in healthcare being adopted during the MOOC? What evidence is there that the MOOC format and materials engaged participants? What evidence is there of participant networks for data science in healthcare being sustained post MOOC?

**Methods:**

The Kirkpatrick Model is a method for evaluating the effectiveness of training [7]. It considers the value of training, formal or informal, across four levels. Level 1 Reaction evaluates how participants respond to the training. Level 2 Learning measures if they learned the material. Level 3 Behaviour considers if they are using what they learned on the job, and Level 4 Results evaluates if the training positively impacted the organisation [7].
Table 1. A description of how each level of the Kirkpatrick was addressed using data points collated

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1: Reaction</td>
<td>Participants' experience of the course was extracted from the interview data about their descriptions of the course components and delivery methods. The level of their participation in the course such as completion rate and participation in course discussions were also collected during the interview.</td>
</tr>
<tr>
<td>Level 2: Learning</td>
<td>Whether the participants had gained knowledge from the course was gauged through their responses to the interview. Their self-reported level of learning in different aspects such as quality improvement in health and care and the tools for carrying out quality improvement as well as whether they had been able to take part as much as hoped was recorded.</td>
</tr>
<tr>
<td>Level 3: Behaviour</td>
<td>Behavioural change as a result of the MOOC was discerned through the interviews, with an emphasis on what had been applied in their workplace, whether this change had been sustained and if the participant aware of a change in their behaviour.</td>
</tr>
<tr>
<td>Level 4: Results</td>
<td>Results were recorded through asking participants if they were involved in, any projects which the participant had contributed what they had learned or gained as a consequence of the MOOC to, or influenced, were noted. Furthermore, the benefits these would bring to the organisation were recorded.</td>
</tr>
</tbody>
</table>

To use the Kirkpatrick method, there must be data available which can answer each of the four levels of evaluation. The data used to accomplish this was participant interviews. Two participants were evaluated using the Kirkpatrick method; this number represents the students who were interviewed.

About the MOOC

Data Science Essentials: Real World Evidence MOOC was run twice, during August-September and October-November 2017. Each MOOC lasted for five weeks. The fifth week of the MOOC was only offered to learners who signed up for certification, available for an additional cost. The
same material was offered in each of the August and October MOOCs. The MOOC required a weekly effort of 2-4 hours.

**Participants**

We invited all learners who took the MOOC to be interviewed. The learners were contacted twice via email over a two-week interval. Only learners employed by Imperial College London were excluded from the study. Initially, 7 participants volunteered to be interviewed, 5 of them eventually declined or did not respond to the interview invitations. The final sample included two participants who were both interviewed. One participant completed 75% of the August MOOC, and the other completed 50% of the October MOOC. Since both participants did not sign up for certificates, they only had to complete four weeks of the MOOC. Interviewees received an information sheet about the study and provided written informed consent for the interview. Ethical approval for the study was obtained from Imperial College Education Ethics Committee.

**Data collection**

The interviews were conducted in December 2017 through conference calls, and only the participant and the interviewer participated in the call. An interview guide with the key topics and questions was used to help focus on the topics of interest. The guide included the interview questions and possible follow up questions. Questions were about participant's background, reasons for taking the MOOC, participant's use of the information in the workplace, participant's interaction with other learners and participant's opinions about the different materials and tools used to deliver the MOOC. The interviews lasted approximately 20-40 minutes and were audio recorded. Interviews transcription was performed by the researcher as a way to start data familiarization [8]. Notes were handwritten during the interview and were reviewed during data
transcription to ensure the accuracy of the transcription. The interviewees did not have any personal or professional relationship with anyone from the research team.

Data analysis

Interview recordings were transcribed verbatim, anonymised and analysed. The primary author (a research assistant with training in qualitative research) was the primary data coder. Thematic analysis of the data was carried out using Braun and Clarke’s framework for thematic data analysis, consisting of six phases: familiarisation with data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and production of a report [9]. Revision and verification of the codes were carried out through discussions with the principal investigator in each phase of the coding. Few changes were made to the codes as a result of discussions with the principal investigator. The Kirkpatrick evaluation method was used following the thematic analysis as a method of theory triangulation to enhance the credibility of the analysis [10]. The Kirkpatrick evaluation focuses on four levels of a training program: reaction, learning, behaviour and results [7]. This method was used to evaluate the participant's opinion about the course (reaction), whether the participants learned from the course (learning), whether they experienced any consequent changes in behaviour (behaviour) and how this impacted their studies, work or broader community (results).

Data management before coding included removing interview questions from the transcripts to keep the coder focused on the primary purpose of the research. Preliminary coding occurred through the transcription of the interviews, reading and re-reading of the data, and systematically open coding the data. Coding was performed manually using Microsoft Word, and preliminary codes were organized in an Excel sheet to be reviewed by the principal investigator. Inductive coding was used meaning that the themes formulated were data-driven
In the fourth and fifth stages themes were reviewed, named and defined and a thematic map was created to review and compare the themes. The thematic map helped reduce the themes and clarify the relationships between the themes.

Thematic analysis is one of the most used methods in qualitative studies and interpreting data by forming themes is “the most applicable” method of analysis for interview data [11]. Previous evaluations of educational and training programmes have used thematic analysis for the interpretation of data such as interviews, surveys, and discussion posts [13-15]. Kirkpatrick evaluation provides a more practical method for evaluating a training programme, and it was used to further evaluate the impact of the MOOC.

Results:

Thematic analysis

Analysis of the semi-structured interview data gave rise to three central themes: ‘learner background’, ‘MOOC learning’ and ‘MOOC’ features, which can be seen in Figure 1.

Theme 1: Learner background.

Learners’ educational background included a Masters in Economic Evaluation in Healthcare and Masters in Biostatistics, and professional experience includes working in the pharmaceutical industry and the healthcare sector and being involved with data science at work. The codes ICT (Information Communication Technologies) related and healthcare related represents learners educational and professional fields that were closely related to the MOOC’s field of interest; the intersection of ICT with healthcare.

Sub-theme 1.3: Topic Significance.
Topic being new/recent
Participants were especially interested in RWE, and the fact that the topic being first of its kind:

“I wanted to get a better understanding of...what defines Real World Evidence in the marketplace because it sounds like a Buzzword, I just wanted to know like, for validation really” (p1)

Topic being related to job
Participants joined the MOOC because the topic was relevant to their job:

“The reason I joined this course is because I anticipated that having, being equipped with this knowledge put me in a better position within my job” (p1)

“I am currently working as a medical science liaison in pharmaceutical industry...currently my role, I am also responsible for Real World data in my company in the [eliminated word] region and its like taking, its only 20% of my time in the job description” (p2)

**Theme 2: MOOC learning.**

**Sub-theme 2.1: Raised awareness.**
Participants expressed their level of awareness using the following expressions when talking about the learning gained from the MOOC: “it definitely made me more conscious…” (p1) and “There are many many sources of datasets I didn’t know they existed” (p2).

“the part of the information governance was very new for me, ... just it puts the whole process into perspective, in a system, like now I know that there is a system existing for payroll data and pharmaceutical, academic collaboration, and they were many excellent case studies” (p2)

Learning of regulations and systems for data collection
Both participants expressed their learning from the MOOC by talking about some of the topics they have learned about like “governance”, “regulations” and “systems” related to data collection.

Future plans to apply learning
Participants were confident about using the information in the future. For instance, one participant expressed that even though their workplace was not yet ready to implement what was learned from the MOOC, the information learned will be very likely to be used in the future: “I’m sure I will get back to them one day.” (p2). Also, the same participant has added about the regulations taught in the MOOC: “...I believe, they will give, they are a very good example of the existing regulations, and also different resources and sources of data sets, I believe this will be very helpful.” (p2)

Also, the other participant has described the MOOC as being a “good course,” that it was “taught better” than a different MOOC about a similar topic and explained that these qualities of the MOOC ensure the use of learning in the future.

Sub-theme 2.2: MOOC application.
Participants had similar reactions to the application of the MOOC in their work or studies; both were not able to apply the learning from the MOOC. The barriers to the use of the learning from the MOOC were reflected in the following codes:

Lack of resources
Lack of resources expressed as a lack of data sources:
“currently in my current role, we, unfortunately, don’t have a data source, but we are planning to discover and to develop some, but I should be, I am assigned to do this, but we did not start yet” (p2)
Lack of resources expressed as lack of time

“so that is difficult to say because I was like in the final two weeks of my job and that health economics consultant, when I started this MOOC, so I didn’t really get to do the applying my knowledge in my work,” (p1)

Different responsibilities

“I probably would say that I did not use it yet because the projects that I work, well the clients that we work with um, they didn’t, they’re not at the stage of, well they didn’t come to us for that part of data collection ...” (p1)

Theme 3: MOOC features.

Subtheme 3.1: MOOC positives.

Each participant had different opinions about what they liked most about the MOOC.

MOOC organizers

“and I just, I was happy to find out that there is a course, an online course about it, by the Imperial College.” (p2)

Teaching related

One participant found the videos to be the most engaging as a teaching method:

“The videos were the most engaging. I like both. I like the videos and the articles, but the videos were more engaging for me. they are easier to follow maybe” (p2)

The other participant found the assessments and the up-to-date recommended links to be the most helpful:

"I like the questions throughout the lesson because it does test you, whether you're actually concentrating or flicking through the MOOC." (p1)
“I did really like the links at the end, where you could find more information, because they were pretty up to date, in the past, in very recent years,” (p1)

**Sub-theme 3.2: MOOC negatives.**

Lack of communication between learners

Participants have expressed not being able to communicate with other learners negatively. One participant used the words “unfortunately not,” (p2) when asked if they were able to communicate with other learners, while the other expressed the experience:

“I lacked the motivation, not knowing who else was doing it...it did feel like a very, very independent experience...Yes, because, well I couldn’t tell who else was learning on the course,” (p1)

MOOC platform related

The other negatives mentioned about the MOOC were more related to the technical issues with the MOOC platform itself. One participant did not find the platform to be “user-friendly” and both believed it would be better if there were more features available on the platform that could allow things like pausing lessons and returning to the same place after logging off and being able to download the videos for offline viewing.

**Sub-theme 3.3: Networking.**

Participants did not communicate or network with others during or after the MOOC, and the reasons seemed to overlap.

Lack of participation

Initially, participants were interested in networking or communicating with other learners who were evident in their attempt to visit the social media page created for the MOOC (accessible
through a Twitter hashtag). The inactivity and lack of participation in the platform was the main reason for not networking.

“when I first started the course, I think it was like the first two weeks, so I looked at the hashtag, which encourage conversation on Twitter, but I did notice that there wasn’t that much going on, I guess because there were so few people actually speaking or having a conversation about those topics, that I ended up not going forward with joining in the conversation...” (p1)

"Unfortunately not, I tried to follow at the beginning the hashtag of the course on Twitter, but I didn’t find it very active, so I didn't follow up after the first week...So I didn't initiate any conversations." (p2)

Interest in networking

Lack of networking during this MOOC did not mean that participants were not interested in networking as they have expressed interest in it.

“it is a very good idea actually. It would be a very good opportunity because you would share relevant material and relevant news and opportunities, yes” (p2)

Kirkpatrick evaluation:

In this section, the key findings from the Kirkpatrick evaluation model are reported.

A unique learning opportunity

Learners reacted fairly positively to the MOOC. Participants found the MOOC to be particularly unique, either because of the topic of the MOOC or because of the collaboration that resulted in this MOOC. MOOC completion rates were different for each participant; 75% or 50%.

Participants’ social media posts participation did not occur, and there was an equivalent reaction
from both implying that not seeing a high level of participation from other learners was
demotivating. Participants reported that the MOOC platform's ease and comfort of experience
could be increased by offering more flexible video and lesson pausing features. Participants
were confident that application of the learning from the MOOC would occur in the future.

New knowledge gained
Participants demonstrated this by discussing the different key topics offered in the MOOC and
explaining their understanding of the topic. For example, one participant gave an example of
RWE data and explained how it could be used. Participants demonstrated their understanding
of information governance, a key topic taught in the MOOC and explained its importance for
data integrity. Further, participants explained what systems need to be put in place for RWE
data collection to occur.

Application in real life
Although participants were aware how the learning gained from the MOOC could affect their
behaviour at the workplace, they were not able to apply the learning after the completion of the
MOOC. Participants' workplace was not ready to implement changes related to the learning
from the MOOC due to the lack of resources. Lack of support from colleagues did not seem to
be reasons for not applying the learning. Participants reported being more confident and
comfortable with topic after finishing the MOOC.

The potential impact of the MOOC
Based on the MOOC’s course description the aim was to teach learners how to “develop new
methods for data analysis” and use of the data to “inform decision-making in healthcare” [6].
Therefore, the potential impact of MOOC would be to demonstrate that new methods of data
analysis were adopted and that the new data-informed decisions in healthcare. Since
participants did not report the application of learning and did not provide examples of new
projects adopted post MOOC, it was not possible to report these outcomes in the current analysis. However, the evidence from the other levels demonstrates that participants were satisfied from the course, believed that valuable new knowledge has been achieved and that the learning will be useful in the future and will affect the participants approach in data collection and use of data.

**Discussion:**

**Principal Results**

Our study used the Kirkpatrick training evaluation model to assess the effectiveness of a MOOC. This was done through thematic analysis of semi-structured interview data with learners, and completing a Kirkpatrick evaluation of the interview data. Overall, the MOOC was effective in reaching the intended target audience, improving learners’ knowledge of the topic and using engaging learning tools. Learners’ application of knowledge in the workplace was highly affected by the workplace responsibilities and availability of resources. Finally, the MOOC could be improved regarding increasing communication and networking between learners.

This study acknowledges the link between the learners' background, interest in the topic and decision to join the MOOC and confirmed that the course had attracted learners from target learner profile. Our results showed that learners were motivated to join the MOOC because of their educational and professional background, because the topic was new and in demand, and because the topic of the MOOC was work-related. Learner’s background and professional goals affect a learner’s decision to join a MOOC. This is especially true when a MOOC has
“professional applications,” which strongly affects learners interest in the MOOC [14]. Learners determined the significance of the MOOC’s topic through its relevance to their professions and their awareness of the topic being new and popular in their professional fields. Results from a previous MOOC evaluation showed that improvement of learning and improvement of job-related skills were both one of the top three reasons why learners joined a MOOC [14].

Participants in this study had a positive recollection of the learning and the educational content of the MOOC. Learning from a MOOC is not a rare occurrence as a study found that MOOC learners, in particular, had slightly better learning outcomes compared to learners in a traditional university classroom [15]. Learners believed that the MOOC helped them raise their awareness about the available resources for RWE data science and were confident the information would help them in the future. A randomized trial found that a MOOC was sufficient to teach physical therapists training on spinal cord injuries [16] and participants in this study have reported increased recognition and understanding of the topic indicating that MOOCs can link learners to professional resources and keep learners updated with the latest knowledge and trends in their field.

Participants mentioned several barriers related to the application of the knowledge from MOOC. A systematic review of randomized controlled trials found that improvement in learning and skills on healthcare-related topics was equivalent, if not higher among learners of online courses compared to learners in traditional settings (e.g. classroom) [17]. However, an increase in knowledge alone does not contribute to the application of the learning. It is suggested that while MOOCs may be successful in providing theoretical knowledge, the application of knowledge is not yet achievable with the current level of MOOCs, which provide little chance for learners to apply the knowledge during the course [16,18]. Although participants did not state this reason as
a barrier for knowledge application, it is still possible that additional opportunities to apply the learning during the MOOC could improve participants' behaviour change in the workplace.

RWE, the main topic covered in the MOOC requires a complicated set of resources such as multiple sources of data, patient protection policies, organizational support and can be very costly to implement [19]. This indicates that even if the learning from the MOOC was effective, the lack of support and lack of resources in the workplace could act as barriers to apply the learning from the MOOC, as mentioned by the learners. Also, the skills learned from the MOOC must be needed in the workplace for the learning to be applied and practised by the learner. This was concluded from one of the participant's responses about not being able to apply the learning due to moving to a new job where data science-related skills were not needed in the job. Although the application of knowledge is a better indicator of learning than the recall and remembrance of knowledge [20], the inability of participants to apply the knowledge from the MOOC in their workplace, lead this study to focus on the barriers of the application of the MOOC learning.

Several factors about the MOOC were reported to be compelling and engaging by participants like the videos and the assessments. Participants reported different things they like about the MOOC like the recommended readings being recent and the videos being easy to follow. Few factors that can be improved about the MOOC were raised during the interview. For example, in this MOOC, the social media platform Twitter, was used to initiate discussion and networking between learners. Our findings suggest that there was a lack of networking and active participation in discussion posts of the MOOC, which participants attributed to inactivity by other learners. However, findings from a previous MOOC showed that 90% of the activity on discussion threads of the MOOC was passive, meaning that most students are only present to view what others have posted [14]. This suggests that even if other learners were more active in
the social media discussions, this would not have guaranteed participant engagement with other learners. Networking in a MOOC can increase the number of MOOC participants [21], increase the learners’ satisfaction with the course [16] and contribute to the learning. Therefore, more effort is needed to increase learners participation in social media or discussion thread posts since networking is not only desirable to learners but is also associated with better outcomes for MOOC learners. Also, because MOOCs are offered through online platforms, the ease of use and the features offered on the platform are of great importance to the learners [22].

Participants agreed that some of the lesson and video pausing and offline viewing features of the MOOC could be improved. Ease of use of the MOOC platform could increase learners’ acceptance of the MOOC [23] indicating platform improvements are necessary to improve learners’ experience and engagement with the MOOC.

Our study’s strengths are that it used qualitative data to assess learning and skills of participants after the MOOC. It is believed that studying the success of an online-learning course should not only focus on the quality of the technology it uses but focus more on the applicability of the information to the learners’ day-to-day activities [24]. Our study focused on how learners were able or not able to use the learning from the MOOC and explored the factors and barriers in the applicability of the MOOC content in participants’ work. To the best of our knowledge, there we no MOOC evaluations that took into account participants' work-related barriers in applying knowledge from the MOOC. Also, the use of interview data was another strength of our study.

Limitations

This study also had some limitations. Due to the lack of data, we were unable to use any pre-course measurements to compare participants' reaction before and after the MOOC. We also
relied entirely on participants' self-reported data, which is subject to bias. Another limitation of our study was our evaluation participants being professionals who were highly involved with data science in their professions, which may have affected their responses regarding the MOOC's content. A limitation of our use of the Kirkpatrick model is that it is intended to be used six months' post-training, wherein this study the interviews took place four months later. Furthermore, the self-reporting of learning in level 2 is at risk of recall bias though was attempted to be mitigated by evidencing examples through triangulation. Nevertheless, our study could help future MOOC evaluations in determining what factors need to be studied in more depth to evaluate the effectiveness of a MOOC and could help researchers consider factors beyond learners' knowledge to understand what can help improve the MOOC learning's applicability in real life.

Conclusions

Results from this study indicate that there is not enough evidence to support if teaching about data science in healthcare through the use of MOOC could lead to the use of new data collection methods that can inform decision-making in healthcare. The study also showed that the MOOC attracted participants that work in fields that use data science in healthcare, that the MOOC was not able to help learners join networks of data science in healthcare during and post MOOC and that the MOOC engaged participants through the use of videos and assessments. The findings from this study provide insights into the applicability of MOOC learning in real life and how it is important to consider learners application of learning in MOOC evaluations to have a better understanding of what and how can MOOCs impact the skills and behaviour of learners.

ACKNOWLEDGEMENTS

We acknowledge the professionals and academics who contributed to the delivery of the MOOC: Data Science Essentials: Real World Evidence: Hassan Chaudhury, Yusuf Ermak, Enda Ridge and Jerrell Schivers.
This work was supported by the Higher Education Funding Council (HEFCE) for England. The content is solely the responsibility of the authors and does not represent the views of HEFCE.

**AUTHOR’S CONTRIBUTIONS**

Data collection and data analysis were performed by the first author AA. Codes and themes resulting from the analysis were reviewed in discussions between AA and EM. EM provided feedback and oversight. AM, JC, DB, GW reviewed the second and third drafts. AA incorporated and addressed the feedback from the authors. All authors approved the manuscript before submission. EM is the guarantor.

**CONFLICTS OF INTEREST**

The ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf was completed by all authors. The manuscript received financial support from EIT Health. All authors declare that they have no relevant conflicts of interest, no financial or other type of relationships that could potentially influence the submitted manuscript. All authors do not have any patents that may be relevant to the manuscript or any relationships, circumstances or conditions that may lead to conflicts of interest. This article represents the authors' individual opinions and may not necessarily represent the viewpoints of their employers. D.B. is a stockholder in Translation Ventures Ltd. (Charlbury, Oxfordshire, UK) and IP Asset Ventures Ltd. (Oxford, Oxfordshire, UK), companies that, among other services, provide cell therapy biomanufacturing, regulatory, and financial advice to pharmaceutical clients. D.B. is also subject to the CFA Institute’s codes, standards, and guidelines, so he must stress that this piece is provided for academic interest only and must not be construed in any way as an investment recommendation.

**ABBREVIATIONS**

MOOC: Massive Open Online Course
ICT: Information Communication Technologies


25. Romiszowski A. The future of e-learning as an educational innovation: Factors influencing project success and failure. Brazilian Review of Open and Distance Education-Teorias Aspectos Teóricos e Filosóficos 2003;