Through Engineers' Eyes: a MOOC Experiment

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CONTEXT
Like the dog that caught a bus, when we caught a MOOC we wondered what to do with it. We decided to invite people to develop 'Engineers' Eyes' through learning basic engineering mechanics. MOOC participants come from a love of a topic or interest in it, but they have other competing interests. They sign on at the click of a mouse, and can just as easily bail out. We had to make our offering interesting. We aimed for friendly, authoritative and fun.

PURPOSE
We wanted to find out about MOOCs from the inside, and see how they could be used, for example for promotional material, or as a part of blended learning.

APPROACH
Although we looked briefly at other MOOCs, we minimised constraints in the creation process and followed where our own thinking led. We assumed that participants would also follow their interests and not be looking for a qualification – "a piece of paper". We would like people to stay in our course, but if they discontinued there was no thought of failure on either side. This provided a wonderful lightness of spirit.

RESULTS
As we finalise this paper we have almost finished the second offering of our MOOC. We have analysed student responses to the first run and they are positive, but there is always room for improvement and we made changes accordingly. We have yet to analyse student responses to the second run, but at first glance it seems that our changes have been well received.

CONCLUSIONS
Our MOOC has been hard work, exciting, instructive, and an insight into the globalisation of learning. It looks good at present, but time will tell. But we have done it and have much experience from practice to share with the educational community on what it is like and how we plan to improve it.

KEYWORDS
MOOC, adaptive tutorials, mechanics, engineering.

Introduction

Since the recent development of massive open online learning platforms such as Coursera, Udacity, Ed-X, FutureLearn (FL) and OpenLearning, knowledge sharing across the globe has been a driving force in the democratisation of learning. Massive Open Online Courses (MOOCs) offer free access to anyone in the world who has an internet connection and an interest in the course topic. This results in large enrolment numbers, usually in the tens of thousands (Agarwal, 2014; Jordan, 2014). With this new educational model, MOOCs can enhance the sharing of knowledge-making between people in varied geographical locations and of differing educational backgrounds, based on a common interest (Vigentini et al 2016). In recent years, MOOCs have become the centre of much media hype, and have been considered to be disruptive and transformational for traditional educational practice (van den Berg & Crawley, 2015; Parr, 2014). The focus has been on a few characteristics of the MOOCs; namely that they are free, consist of very large numbers of students, have low retention rates, and that their quality relies implicitly on the status of the institutions delivering them. Our MOOC arose from a simple suggestion. "*I think we should develop a MOOC on Engineering Mechanics. It could build on our work with Adaptive e-Learning Tutorials, and to keep the course accessible to everyone in the world, complex concepts could be demonstrated using commonly available items. After all, physical reality is physical reality however you look at it.*"

Our MOOC could provide:

- a chance for us to assess the value of MOOCs from the inside
- a resource for on-campus students
- a resource for blended learning
- a marketing opportunity for our university
- a step along the road to democratising learning

Who would our MOOC be for? A previous MOOC on a related subject had awoken us to the unexpected situation that our demographic would cover an age range from 16 to over 65, some still at high school and many others (including practitioners in the industry) holding higher degrees. This is consistent with general experience in other related MOOCs. How could we make our MOOC accessible and interesting to this eclectic student body? We decided to invite people to develop 'Engineers' Eyes' through learning basic engineering mechanics. We aimed for a style that would be friendly, authoritative and fun.

Although this distinction has been challenged (Lukes 2012; Conole 2014), there are two well recognised types of MOOCs: cMOOCs (Siemens 2005) – or connectivist MOOCs – focusing upon community and peer interaction, and xMOOCs (McAuley et al. 2010; Rodriguez, 2012), normally driven by content and knowledge, often using automation of activities in order to accommodate large number of students. Our MOOC would sit somewhere between the two. We assumed that participants would follow their interests and would not, in the main, be looking for a qualification – "a piece of paper". We would like people to stay the course, but if they discontinued there was no thought of failure on either side. This provided a wonderful lightness of spirit.

MOOC Design

The naming of our course was carefully selected to represent the form and intent of our MOOC: "*Through Engineer's Eyes: Engineering Mechanics through experiment, analysis and design*" (here after referred to as TEE MOOC).

We wanted to introduce learners to the world-view of an engineer by demonstrating how engineers use analysis to understand their surroundings and to predict the behaviour of the things they design. Accordingly, we developed a range of experiments that learners could carry out by using commonly available items, such as rubber bands, cardboard, string and toy vehicles. These would anchor their studies in practical reality and provide experience on which to base their studies of classical analysis. But for engineers, analysis is not an end in itself, so to show how they use this capability we introduced design activities.

The technology behind the MOOC

In order to design, develop and implement the MOOC there were some critical choices made along the way. The FutureLearn platform was selected to host the course. This was informed by a number of reasons: story-telling, neat and simple mobile-phone-friendly experience, focus on learning rather than certification, and being open to exploration rather than focusing on mastery.

An important component in our MOOC included the addition of Smart Sparrow (Ben-Naim & Prusty 2010; Prusty et al, 2011), which is a learning design platform that enabled us to incorporate rich, interactive and adaptive e-learning courseware. The addition of adaptive tutorials in our MOOC aimed to complement activities in our learning design. Another interesting addition in our MOOC was the inclusion of 'Retro Tutorials', –low-tech, paper-based exercises typically found supporting tutorials in university level courses – to assist participants in consolidating their learning.

Structure

The course was modularised following a weekly structure that in the end became seven weeks which covered the concepts in Table 1.

Table 1: Structure of the TEE MOOC

topic	experiment	analysis	design
Elastic properties	Load-deflection of a rubber band	Stiffness	No design activity
Forces that act at a point	Measuring forces that act at a point	Adding forces that act at a point	Cables for suspending a loudspeaker
Forces on a rigid body	Moments, forces on a rigid body	Equilibrium in two dimensions	Connections for a folding washing line
Centre of gravity	Finding cg by suspension and balancing	cg of a composite body	Specifying the ballast weight for a model glider
Friction	Basic friction model, tip/slide, rope around a bollard	Basic friction model, tip/slide, rope around a bollard	Belt drive for a model car
Work and energy	Rolling resistance, aerodynamic drag/lift	Rolling resistance, aerodynamic drag/lift, work and power	Design evaluation of electric vehicles
Impulse and momentum	Shove ha'penny	Impulse/momentum	No design activity

Although this is essentially a course in engineering statics we were not bound by convention, rather for each week the engineering story line controlled the content. So, for example in week three the design activity introduced double shear in bolts – a concept usually encountered in mechanics of solids rather than statics/dynamics. Or, again, week six introduced work/energy which usually waits for a formal course in engineering dynamics.

Learning design

Learners were led through the course by short videos accompanied by supporting text resources. We generated over 50 videos in total. These were filmed in-house with motion graphic work outsourced. Filming the videos in-house enabled us to have greater control of the production of the MOOC as we were not restricted by budgets or tight production schedules. Outsourcing the motion graphic work freed up development time as this is a labour intensive task.

Each week an introductory video set the scene, followed by a video (sometimes several) on the week's experiment. If the learner decided not to do the experiment they nevertheless could identify with the activities because of the familiar nature of the equipment. ‘Padlets’ were added to each experiment. These are virtual walls that allow participants to share images of any experiments that they attempted. Our decision to commence each week of the course with an experiment was aimed to spark participant interest in the topic and ground it in physical reality. Further videos explained the analysis and led learners through the design process. Other activities included on-line adaptive tutorials and 'retro-tutorials', so called because they were in the classic style of paper and pencil. Discussion was encouraged.

Recognising the wide range of backgrounds of our learners, we assumed only basic trigonometry and algebra. Calculus was not required. However, we did acknowledge that mathematics is the language of engineering analysis, and part of its beauty.

Running the MOOC for the first time

The structure held up well, and our MOOC generally went smoothly, based on participant feedback. As with the first run of any major development, there were some typos, errors and omissions, but these didn't get in the way. In fact many of the learners were happy to find these and start a discussion. However, we kept a close eye on the comments and made rapid corrections. Learners appreciated our engagement in the process, and we all gained from it. Many of the learners who found errors or omissions were clearly older participants with a background in engineering or even in engineering education. Conveniently they often got ahead of the nominal schedule and cleared the way for later learners.

Making sense of the data deluge

One of the key promises of MOOCs is the availability of large amounts of data generated from the participants' interactions, both with the course and with other participants. This was the case of TEE with data coming from the FL platform and SmartSparrow. This section summarizes information about the participants, what they did and what they thought about the experience.

Table 2: Overview of learners’ characteristics based on survey responses (N=119)

	demographic	response rate and CI*	Category distributions
TEE_1	Gender	9.26% ± 0.68%	Male (71%), Female (28%), Other (1%)
	Age range	9.09% ± 0.67%	<18 (6%), 18-25 (26%), 26-35 (26%), 36-45 (13%), 46-55 (11%), 56-65 (9%), >65 (10%)
	Employment	9.22% ± 0.68%	Full time worker (34%), Full time student (20%), Retired (10%), Looking for job (10%), Self-employed (9%), Part time worker (7%), Unemployed (5%), Not working (4%)
	Highest level of Education	9.29% ± 0.68%	Undergrad degree (40%), Secondary (25%), Master degree (14%), Tertiary (12%), Less than secondary (6%), PhD degree (4%), Professional (5%), Apprenticeship (1%)
TEE_2	Gender	3.94% ± 0.01	Male (62%), Female (37%), Other (1%)
	Age range	2.1% ± 0.01	18-25 (33%), 26-35 (23%), 36-45 (14%), 46-55 (11%), 56-65 (6%), >65 (3%)
	Employment	2.1% ± 0.01	Full time worker (33%), Full time student (26%), Retired (3%), Looking for job (11%), Self-employed (9%), Part time worker (7%), Unemployed (5%), Not working (7%)
	Highest level of Education	2.1% ± 0.01	Undergrad degree (40%), Secondary (19%), Master degree (19%), Tertiary (9%), Less than secondary (5%), PhD degree (4%), Professional (3%), Apprenticeship (2%)

** Response rate for the question based on active learners ± (Margin of error with 95% confidence)*

About the participants

Through the long build-up period before the course was launched nearly 7000 learners registered for the first run of the course with 40% actively engaging with the course at some point while it was open. Similar to the patterns already identified with the funnel of participation (Clow, 2013) a much smaller proportion (7%) of these 'completed' the course. The figures are slightly lower in the second run (4337 learners, 36% active and 2.5% completing)

'Active learners' are those who actively engage with some content while the course is open, and 'completing' refers to those who mark at least 90% of the steps in the course as complete. Because of the nature of the platform, active learners might have visited and carried out the learning activities, but might have not tagged the step as completed: therefore this is likely to under-estimate the effective number of *completers*. As expected by design, only a small proportion of learners obtained a paid certificate.

There are two sources of demographic information in FL: a profile survey asking basic information such as age, gender and level of education, and a pre-course survey asking more about motivation to enroll and goals. As both are optional, the information emerging should be used with caution as the responding sample (about 10%) might not be fully representative. Yet, it provides a useful portrait of participants.

In particular, from the sample of responses, the typical learner in the TEE MOOC was male (71% of respondents), aged between 18-25 (26%), in full time employment (34%) and with an undergraduate degree (40%). The summary table below provides an overview of the distributions. This did not change in the second run (see Table 2)

What did participants do?

From the logs of interaction with the platform it is possible to identify a number of trends. First of all, those who engaged with the content spent between a 90 minutes to two hours on average per week. This equates to roughly 5-10 minutes per step. FutureLearn uses the concept of 'step' which can incorporate a variety of artefacts including articles, video, discussion, quiz, exercises etc. Figure 1 provides a summary overview of the time spent in the course by active learners.

weeks	N Steps	Avg mins to complete a step	Avg mins spent in week
week 1	13	7.2	93.09
week 2	16	8.1	129.72
week 3	20	6.5	130.39
week 4	18	5.1	91.38
week 5	17	5.4	92.56
week 6	16	5.1	80.97

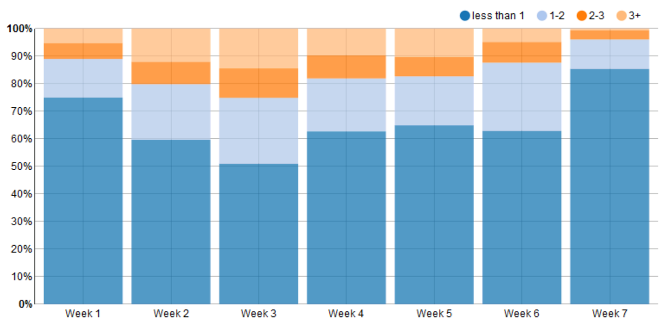
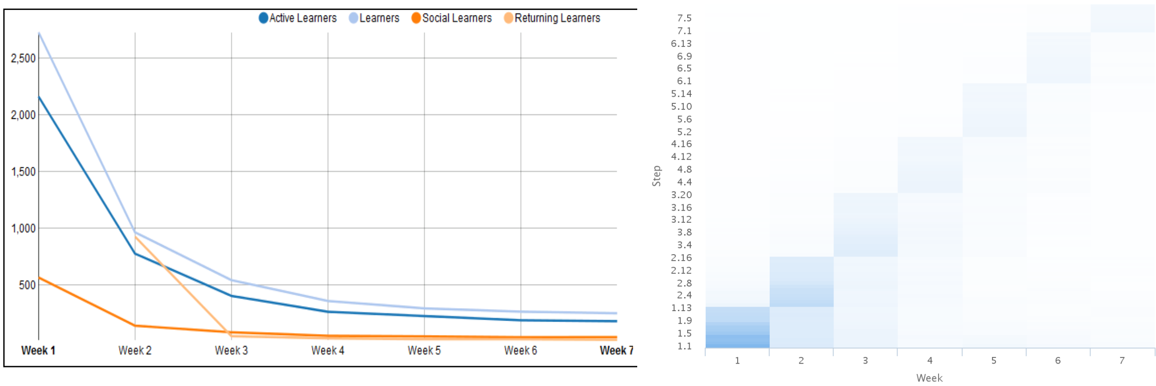


Figure 1: average time spent per step and per week (left) with actual distributions (right)

As already documented (Agarwala, 2014; Kizilec et al, 2013), the number of learners engaging throughout the length of the course drops considerably. Figure 2 shows the number of participants engaging in different types of activity according to FL definitions. This is also demonstrated by the volume of activity in the number of steps completed in the first week (16474) compared to the last week (2539).

Despite the drop in participants and volume of activity, consistently across the course about half the learners visiting a step mark it as complete: this increases to 77% after week 3 demonstrating that some learners may be exploring the course, but over half of the participants remain 'hooked' and complete what they started.

Another pattern which was already highlighted in Vigentini & Clayphan (2015) is the linear pattern of engagement week on week. Learners seem to follow the course in a traditional way, completing activities assigned to a particular week rather than leveraging on the availability of all content at any time.



Registrants are users who enrolled in the course as a learner. **Learners** are users who have at least viewed at least one step at any time in any course week. This includes those who go on to leave the course. **Active learners** are those who have completed at least one step at any time in any course week, including those who go on to leave the course. **Returning Learners** are those who completed at least a step in at least two distinct course weeks. These do not have to be sequential or consecutive, nor completed in different calendar weeks. **Social Learners** are those who have posted at least one comment on any step.

Figure 2: Number of learners completing and visiting steps by type of learner.

As expected with the design of the course, videos were the most visited and completed step. Figure 3 shows the most frequently visited step types and the transitions between them, from a total of over 42000 visits.

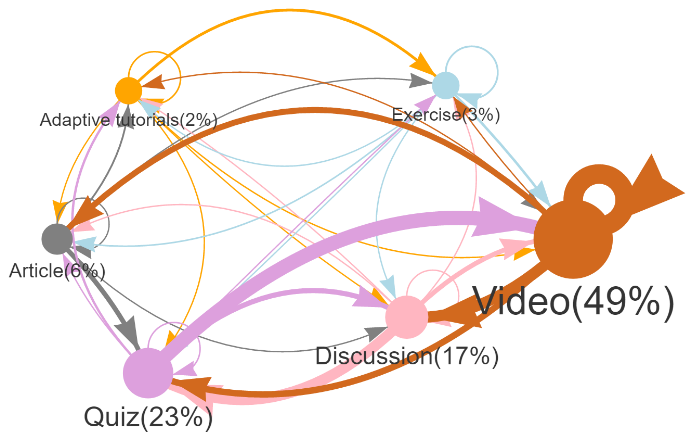


Figure 3: Most visited steps and transitions between steps.

Figure 4 shows the distribution of the attempts to respond to each formative quiz in a format that enables instructors to quickly identify more difficult questions, that is the ones requiring multiple attempts (red, orange and yellow sections).

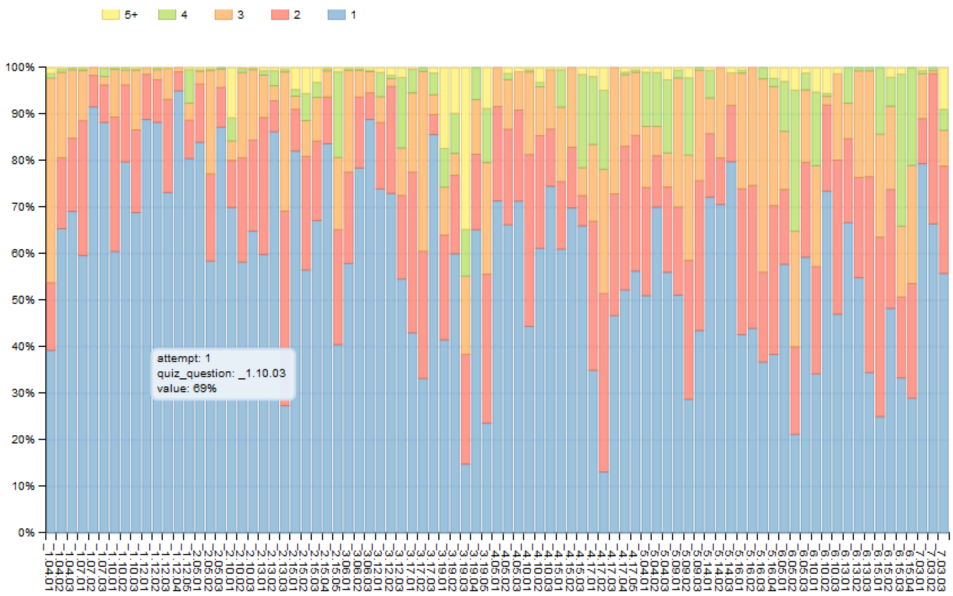


Figure 4: Number of attempts per quiz (up to 5+): on the horizontal axis is the quiz sequence throughout the course –more difficult quizzes show as smaller proportions of blue.

What did participants think about the MOOC?

The effectiveness of the MOOC was evaluated via feedback activities placed in the same weeks as the adaptive tutorials, and via the open comments available in all steps. Mini surveys using the Qualtrics™ tool, presented three questions which randomised answer options in order to ensure an equal distribution of responses and minimised the participants' efforts. The questions asked 1) about the experience with the week's content, 2) the reasons why learners engaged and 3) their preferred modes of engagement in relation to their goals. The top five reasons why learners enrolled in the course are listed in the table below (participants could select more than one reason, therefore the percentage represents the proportion of respondents picking the option). It seems apparent that the challenge posed by testing one’s knowledge and completing the practical learning activities were the most valued aspects in terms of what learners perceived as completion.

Table 3: Overview of what learners’ consider successful course completion (N=119)

Question options	preference
Testing my knowledge in specific topics	30.17%
Completing most learning activities (i.e. 'retro' tutorials and design tasks)	26.72%
Completing most quizzes	25.86%
Completing the Adaptive tutorials	25.00%
Watching most of the videos	23.28%

Learners were specifically asked about their preferences for different aspects of the course. Table 4 provides an overview of what they liked most and least. Interestingly, the cohort of participants enrolled seems to prefer an individual sort of engagement, challenging themselves with the material and activities rather than leveraging on the social interaction and peer support in the forums.

Table 4: Overview of learners' top and bottom preference for learning activities (N=119)

Question options	tot pref
I like the flexibility of learning at my own pace in the course	96.16%
I use the activities, quizzes and assignments to test whether I learn the concepts in the course	96.00%
In a course like this, I prefer interesting material, even if it is difficult to learn	92.31%
I try to understand the material in this course by making connections	84.00%
It is important for me to try to understand the content of this course as thoroughly as possible	83.33%
When watching videos, I try to relate the material to what I already know.	83.33%
When I can't understand the material in this course, I ask other students in the forum for help	10.71%
I discuss with my other participants to find out how I am doing in this course	8.34%

Table 5 provides an overview of learners' satisfaction with different aspects of the course. From the feedback participants who responded were highly satisfied with the experience. However, most importantly, the content presented in each week encouraged them to continue on and explore more of the course, which achieved the key aim set when we started the journey – to keep participants 'hooked' in.

Table 5: Overview of learners' satisfaction with different aspects of the MOOC (N=119)

Question options	tot pref
This week encouraged my interest to explore more	100.00%
Overall, I found the experience intellectually stimulating so far	94.49%
The material was presented in an engaging manner	94.44%
The goals and requirements of this week were clear to me	93.94%
Overall this Week met my expectations	87.39%
Examples, illustrations or real-world cases were used effectively to explain	86.36%
The lecture videos of this week helped me to learn	84.21%
Interacting in the discussion helped me to clarify things I did not understand	61.91%

Running the MOOC for the second time

At the time of i finalising this paper we have almost finished running the course for the second time.

Based on the evidence gathered in the first run, we retained the general format and style but implemented changes in structure and in the detailed design of activities.

We simplified the overall structure by bringing the discussions that were originally separate steps into the step that they related to. We hoped that fewer steps would make the task appear less intimidating to learners and simplify the job of instructors by reducing the number of places they had to monitor. At the same time we clarified what this discussion might cover by introducing 'talking points' in the text for each step.

We had noticed a steeper drop in engagement during week three of the MOOC, so we tightened the story-line for that week and split its Design step in two parts. This is the most important week in the course so it was vital to get it right.

We also revised the adaptive tutorials. On a technical level we improved the UI by:

- enhancing the accessibility of the adaptive tutorials for mobile devices such as iPads,
- creating several new drag-and-drop activities,

- improving the adaptive feedback, and
- adding better quality LaTex equations.

Furthermore, to help orient students to the new technology found in the adaptive tutorials we added general information screens at the beginning of each Adaptive Tutorial lesson

Feedback suggested that we had too much information in some lessons. In response we chunked some of our adaptive tutorials, such as the one on Free-Body Diagrams, into smaller learning segments to make them easier for learners to understand and complete in their limited available time.

We have yet to analyse the student responses formally, but learner contributions to discussions have been positive. Particularly noteworthy have been the many positive responses to the simplified and restructured adaptive tutorials (some examples below). It also seems that the week 3 simplifications have had a positive effect.

> *That was fun. Quite a difference from learning on paper.*
>
> *That is a very nice piece of software to show free-body diagrams with and show general force interaction.*
>
> *Good tutorial. Really helped me understand how to show forces properly.*
>
> *These adaptive tutorials help bring the FBD concepts together quite well for me. The trial and error and explanations at the end make things very clear.*
>
> *A great way to learn while playing.*
>
> *Your Adaptive Tutorials are great. Thank you.*

The most useful indicator so far is that in week 3, in the second run run 35% of participants spent between 1 and 10 hours on learning activities (including adaptive tutorials) compared to about 24% in the first run, while a smaller proportion of students spent less than 1 hour.

Conclusion and future directions

Our MOOC has reinforced for us how important it is to analyse the learning experiences of the courses we offer as part of the cycle of continuous improvement. Through designing and developing this MOOC we have been able to reach thousands of students, but this brings with it correspondingly increased responsibility to do it well. By leverage on the data we can make informed choices about the design of the course and thereby improve the learning experience. Our response has been to experiment and learn from the efficacy of ed-tech innovation, whether it is in MOOCS, adaptive technology, or in learner analytics.

In this way we have created a data-driven course development process that provides students with the *best* learning experiences possible – wherever they are in the world –.

There are still challenges in accommodating the wide demographic. For example, we kept the mathematics as simple as we could, but even basic algebra and simple trigonometry challenged a number of learners, as we read in the discussions.

One learner was concerned about 'failing' because he found the maths hard. He was reassured to hear that 'failing' did not make sense for our MOOC. Because assessment is not at its core, he felt able continue with the course, and benefit, even if he did not understand it all.

Our aim has been simple: to offer to a wide range of people an understanding of engineering mechanics through experiments, analysis and design, whether for general interest or in preparation for an engineering future. We are offering them all a chance to see the world "Through engineers' eyes" and as explained in Khawaja et al. (2013) this is an effective approach.

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