WEB-BASED MATHEMATICS

Some 'dos' and 'don'ts'

Esther Yook-Kin Loong
Deakin University
esther.loong@deakin.edu.au

This case study describes an "out of field" teacher's use of the Internet to teach a range of mathematical topics in a modified Year 8 mathematics class. It highlights the importance of three factors for implementing a discernible web-based teaching strategy: appropriate choice of web objects, effective "virtual" pedagogy, and technical support and expertise. Based on these findings, a framework is suggested for constructing an effective teaching strategy to support the use of virtual resources in the actual mathematics classroom.

The Internet has a plethora of resources that could potentially be used to enhance the teaching and learning of mathematics. I made a simple classification of these resources based on the degree to which they allowed a user to interact with them (see Loong, 2001; Loong, 2003) and advocated a mapping of these resources to the mathematics curriculum (Loong, 2003). Each of these resources was called a web object. Many theories and frameworks have been put forward to posit the use of computers and information and communication technology (ICT) in education (Bigge & Shermis, 2004; Galbraith & Goos, 2003; Kutzler, 2010; Mishra & Koehler, 2006; Wallace, 2004) and some of these perspectives are used to explain what is seen in this study.

This paper looks at how a teacher used different web objects for various mathematics topics, the decisions made and their impact on the teacher and the students. It reviews the pedagogical structures that were necessary for the approach to succeed and discusses how these were relevant. Technical problems that arose are highlighted and discussed. Based on this case study, suggestions are made on some ways forward to improve teachers' use of the Internet in the mathematics classroom.

The setting of the case study

This case study is drawn from observations of nine mathematics lessons in a Year 8 (13 year olds) modified class at Blue Lake High School (pseudonym) over a period of about three months. A modified program is typically one which differs from the standard program and is structured to meet the academic needs of low achieving students. Peter, the teacher who taught this class, is a very experienced science teacher who was asked to teach mathematics. He claimed 'I've been allocated the least able group, the strugglers in other words, so the students here do not know their times tables. Their basic maths skills are probably at Grade 3 or 4 level? Probably maximum Year 5?'

Peter considers himself a "novice" in terms of Internet competency. He had used the Internet more for his teaching of science than for mathematics and had little professional development on the use of the Internet for mathematics. He saw this project as a means to increase his repertoire of ideas for teaching mathematics. As a result of the flexibility afforded in a modified program, Peter decided to carry out a series of web-based lessons to see if the students could be more engaged. The lessons ran for several weeks and covered different topics such as fractions, algebraic expressions, decimals and coordinate geometry. Peter selected the web objects that he felt were suitable for the concepts that he was going to teach or had taught and which he thought were appropriate for this group of students.

Data for the case study were obtained through class observations, semi-structured interviews with teacher and students, as well as lesson plans and worksheets. All conversations were audio taped with the interviewees' consent and later transcribed.

a) Evolving choice of web objects for mathematics topics

When observations started, Peter had already taught fractions in previous lessons. He chose worked examples from a website for the students to read and work with different aspects of fractions that he had taught. He selected a webpage that had eight different sections on reducing, multiplying, dividing, building, adding and subtracting simple fractions (see Figure 1). Students had to read text that explained how to reduce, multiply and divide simple fractions and then solve between one to five questions from an instruction sheet prepared by Peter.

The worked examples and exercises are what would be categorised in Loong (2001) as non-interactive resources that are text–rich expositions or exercises. These resources require students to do a considerable amount of

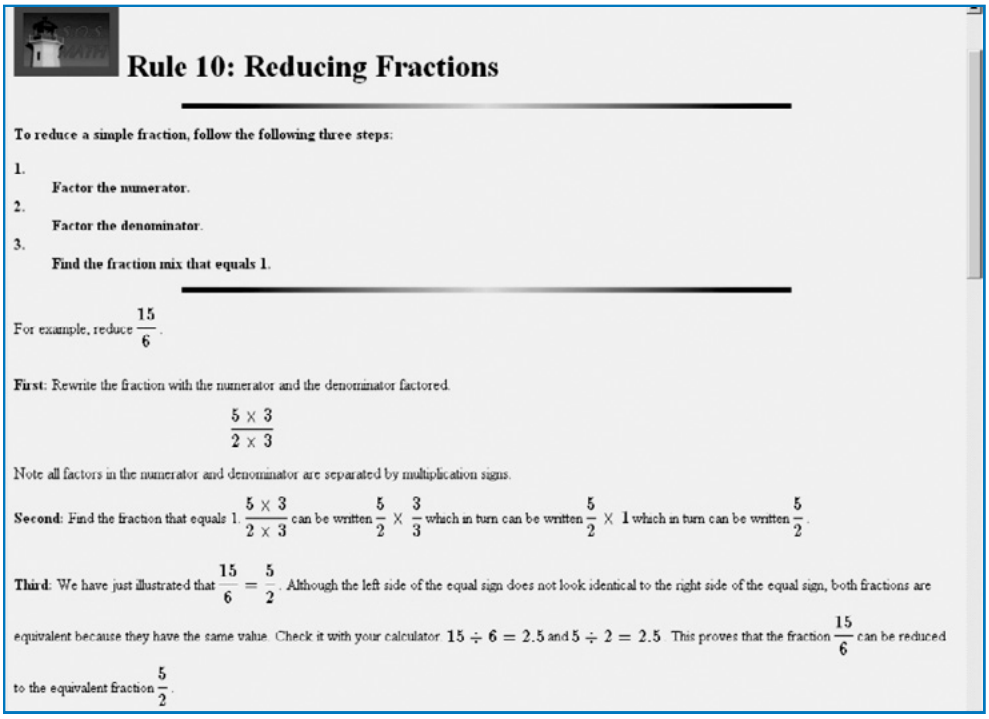

Figure 1. Screen capture of a web page showing worked examples.

reading and text-based exercises. Peter had envisaged that students would need three lessons to complete the exercises up to the dividing simple fractions stage but that did not materialize because of what Peter claimed as "various problems with just logging onto the network, the slowness of the network… you not only got the slowness of the students but it's also the fact that the network is not as quick as an individual single site computer…"

When interviewed as to the reason for using the Internet for the series of three lessons on fractions, Peter replied, "The reason was engagement, to improve engagement with an area that I knew they would have difficulty with given their very, very basic understanding of mathematics."

Peter had hoped to achieve what Bigge & Shermis (2004) described as "explanatory understanding levels of teaching and learning using the computer" where the computer is used to promote understanding of a generalization, process, theory, or principle by using illustrations, numerical data, literary examples, graphs and charts and so forth. When asked if this approach was different to students working from a textbook, Peter replied:

> Probably not a lot. The difference was I wasn't doing the talking. The intent was that they would do their own learning… if they've done one or two of them, they would get a general flow and be able to work more quickly… I hope there's more ownership on the learning scale by the students whereas if I deliver, I write the examples up on the board

But Peter soon realised that the use of the worked examples was not effective: "The reality is it's probably not a lot different from what's on the textbook in terms of the textbook approach, it just takes a lot longer."

When asked if he thought the objectives of the lessons were achieved through the series of lessons he replied, "Er, no. It's just too slow. The students are slow anyway and you only need a minor interruption and that minor interruption for this kind of students can become quite major."

When students were asked how the Internet has helped them learn fractions, there were mixed responses. Matt, a student, replied that, "I reckon it's good. It just helps you… You don't have to depend on the teacher. You can find out yourself and it's got answers and things … it get kids a bit more interested doing things on the computer than just listening to the teacher."

Others said they did not enjoy the Internet lessons on fractions because of the following reasons:

"Because I didn't really understand it," said Bo.

"I didn't really understand how to do it because they like didn't explain it properly. I found that it was

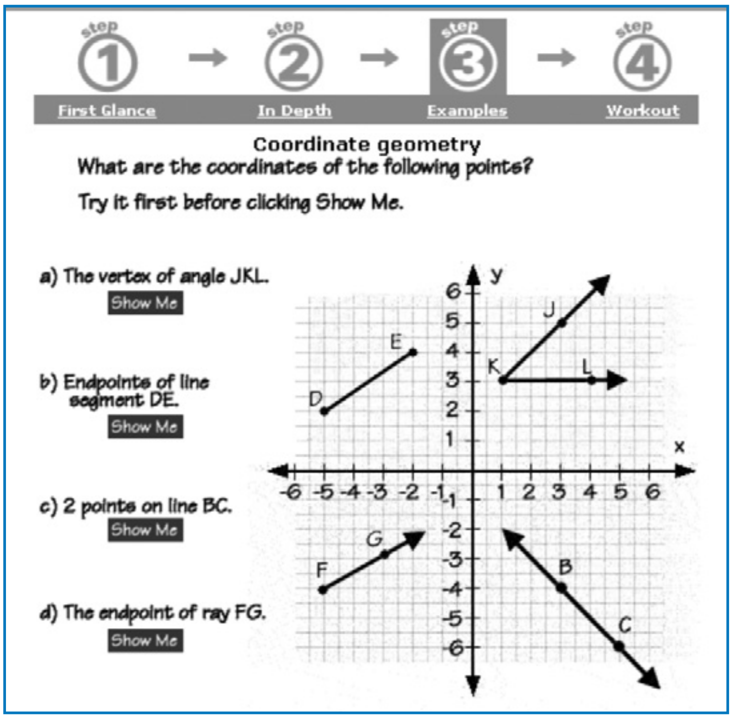

Figure 2. Screen capture of an exercise on coordinates. Source: http://www.math.com/school/subject3/lessons/S3U1L2EX.html

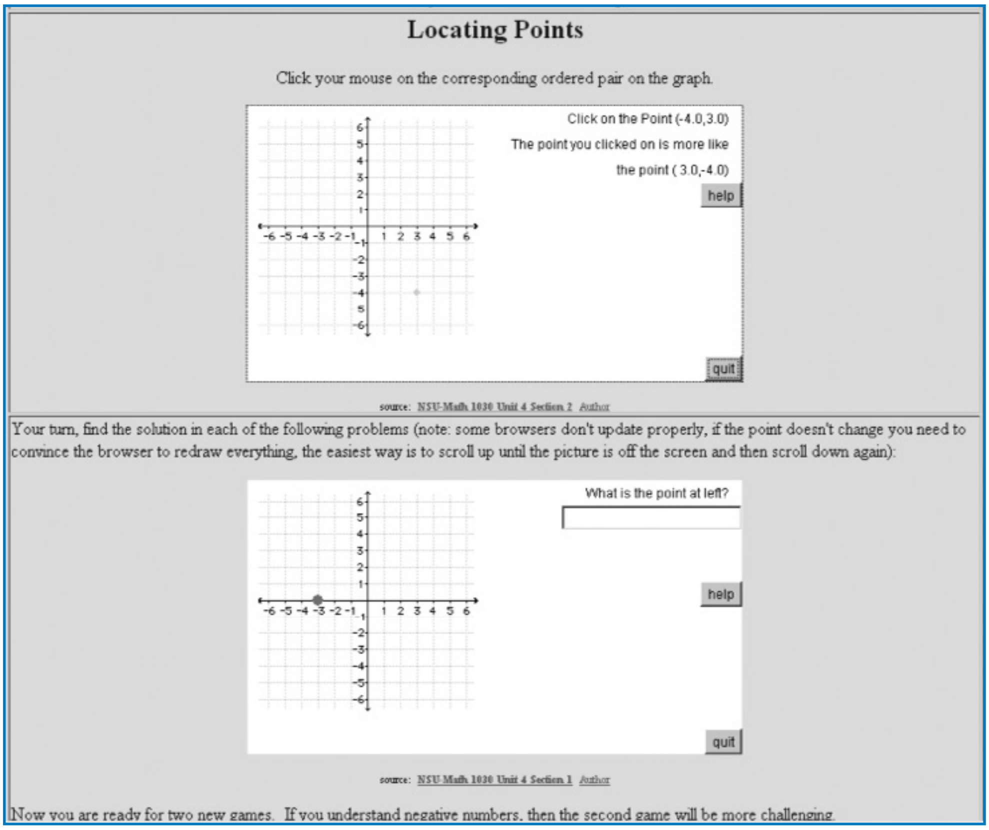

Figure 3. Screen capture of 'Locating Points' applet in response to an incorrect answer. Source: http://staff.argyll.epsb.ca/jreed/math7/strand2/2102.htm#I1

good, like when you click on the answer, the answer came up but I didn't find that they explained it very well," said Alice.

In the first lesson, observations revealed the class was chaotic and students were not on task. Peter reflected on the lessons and realised that the worked examples required too much reading and students were not motivated. He decided to utilise some of the interactive exploratory web objects for Coordinate Geometry (see Figures 2 and 3).

Peter's comments on the lesson were revealing and confirmatory of the progress that these students were making with the interactive Web objects. In the lesson preceding the 'Graphing a Line' activity (see Figure 4), Peter found that students had difficulty converting given information into a table of data and producing a graph from it: "Yesterday's lesson which was a normal classroom lesson… We were doing exercises out of a book, graphing exercises, they had to create a data table from some information and convert that into a graph… They had found that pretty difficult…"

Peter felt that the interactive web object (Figure 4) was useful in helping students make the connections between the variables: "…but today they didn't

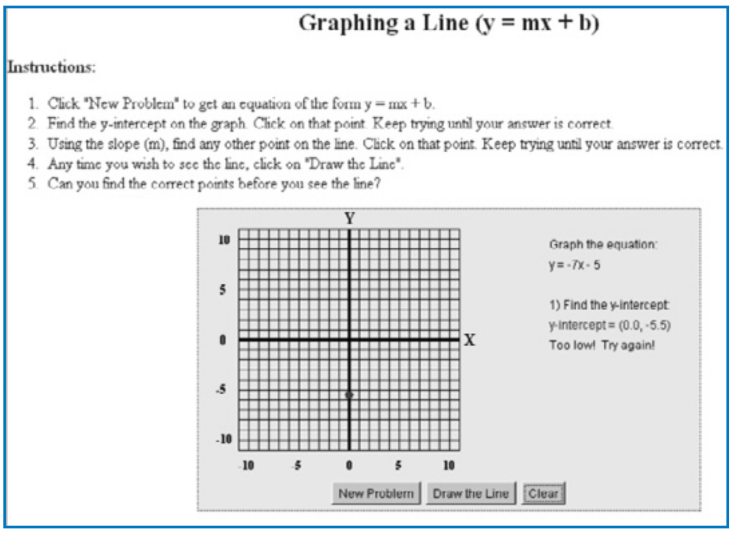

Figure 4. Screen capture of an interactive grapher.

have to create a data table but they did get the concept of the relationship between the y and the algebraic expression which I thought was an important plus for today's work."

Peter was happy that by supplementing the graph and data construction of the previous lesson with this, he had used a much more mathematical approach. He could see the value of using an interactive web object to reinforce what had been taught in the previous lesson: "I don't think they would have got that necessarily from doing their work yesterday. So I think putting the two together the two approaches is a useful way to go. The website we used today had a different approach, much more mathematical approach which we didn't have."

When interviewed again after the sixth lesson using the internet, Peter remarked that, "I think the lessons have been good, I think they've improved. I guess you would have perhaps seen the shift. The students are more able to log on more quickly, and things of that nature, and they are aware of the fact that it's a different way of presenting mathematics, I think they've appreciated that."

One of the students, John, said he really liked doing this on the Internet and was very keen to get on with his exercises. John was one of the students who said in an initial interview that he didn't like mathematics and didn't do well in it. For this student, the interactive exploratory Web object helped him see the connections as well as where his errors lie (see Figure 4): "It will tell you... you're too high... you've got to go down a bit more, and it tells you you're too below or like somewhere around that area you can pick it... it's there if you like need it, you have to go back and review it if you keep getting it wrong, and if you want to see where you went wrong."

He also commented that by interacting with the Web object, "it's easier, (so) you know what you're doing" and "you don't have to keep asking the teacher". This statement seems to imply that he thought that the visual representation of the graphing exercise enabled him to get a sense of what was happening. He shared, that if he had Internet access at home he would like to do some of these activities so that he could 'get better at it, come back to school and get better marks'

Peter had capitalised on the "compensational" support (described by Kutzler, 2010). afforded by the interactive exploratory animated investigations to engage 'mathematically challenged' students. As evidenced by John's story, the interactive exploratory investigation enabled them to continue to do the mathematics despite their particular weakness in this area of mathematics. He ensured that the purpose of the lesson was appropriate to this group of students with their modified program (Galbraith and Goos, 2003). Normal 'teacher chalk and talk' and setting up of tables and graphs had been difficult for these students. Students like John had found that "it's easier, so you know what you're doing," implying that making tables and drawing graphs are abstract activities and lack meaning. The use of the interactive web object which motivated and engaged these students cognitively and visually meant that this strategy of using the web objects provided an opportunity for the modified program to succeed. This web-based activity had also contributed to the desired learning that Peter had planned: that students appreciate the relationships in the algebraic expression through the use of the complementary approaches of "by hand" drawing of graphs as well as interactive graphs on the web.

To ensure that the strategy worked, Peter had set up boundaries to the task. He was the one who determined where the students went to in cyberspace. He ensured that the disciplinary context was valid, that is, the web object taught the mathematics that he wanted them to learn. He ensured that the web object was from an authoritative site and was stable and active. The appropriateness of the web objects to this group of students was tied closely to how well these web objects met the intended objectives. From this case study it seemed that the teacher's content knowledge and discernment when choosing suitable interactive objects was crucial to the success of this strategy. This is consistent with the technological, pedagogical and content knowledge (TPACK) framework advocated by Mishra & Koehler (2006). A web–based interactive task that is based on reading worked examples and clicking on answers might not be as effective as tasks that present powerful visuals for concept development or that allow for student manipulation of variables to see the changes. It is thus useful for teachers to be able to identify the type of interactivity afforded by the web object and to make a judgement on its potential to engage students mathematically.

b) Pedagogical structures needed for success

Similar to a non-technology aided class, certain pedagogical techniques are necessary and beneficial for the management of web-based lessons. These include setting up routines and instructions, and checking students' online work.

In each of the lessons Peter prepared an instruction sheet which showed the uniform resource locater (URL) of the webpage students had to go to, what they had to do and questions which had to be answered. This is an important first step in ensuring the objectives of the lesson are achieved. Nowadays with social bookmarking sites such as Diigo, the student can log on from any computer and still be able to access the bookmarked page easily.

Having a routine helps students to move into whatever task they had to do faster than when there was no routine. In this case, having the worksheets and marking some of the sites that were to be used at a later time as "Favourites", helped set the disciplinary context for a better organised web-based mathematics class. Resources on the Internet are usually not placed in any particular framework or sequence that follows teachers' curricular needs. Teachers have to work that sequence into a disciplinary framework for its use to be effective (Wallace, 2004). By having a list of related hyperlinks on a particular topic, Peter had essentially formed a simple curriculum for that particular topic. Not only does book marking the web page and other related web pages create a disciplinary framework for the students, it is obviously a useful time-saving pedagogical strategy to put in place in a web-based lesson.

One difficulty that arose was related to the reading ability of the students and their typing skills. When URLs were very long, students tend to make mistakes while typing them. To overcome this, the sites could be pre-loaded on the school Intranet, or a hyperlinked URL inserted in electronic mails sent to students, in an electronic word file or as hyperlinks in a class wiki. Such organisational techniques are time saving and reduce the frustration of typing long and wrong URLs.

To ensure proper monitoring of student progress, teacher checks are essential. Peter ensured that the students had given the required response by sighting what was done on the monitor, or from students' results in their exercise book or as a result of interactions on the prepared worksheet.

When interactive Web objects are used and screens are constantly changing, having a teacher check in place means that monitoring of student progress is more systematic and informative to the teacher. Students' perceptions of teacher checks are varied. While some find it frustrating to have to wait for the teacher to check before proceeding, others see value in getting some form of feedback on their current work. Teacher checks are important forms of feedback to the teacher about the progress of the students, and they help keep students on track. As Wallace (2004) observed, pedagogical context on the Internet is rather elusive. It is much easier to monitor the work of students when working with other resources than when they are online. Unless tasks are constrained by designated links and work from the screen is sighted, it is a challenge for teachers to know where students are, in their search for knowledge on the Internet. Under these circumstances, presetting the boundaries enables students to focus on the mathematics concept to be learnt. These combined pedagogical strategies of designating links and teacher checks help to curb and reduce inconsistencies. Whilst students were free to pace their learning according to their own needs, the tasks were done within the confines of the boundaries promoted and set by the teacher. Other disciplines like literacy, however, may prefer less structured and less 'sanitised' forms of exploration (see Burnett & Wilkinson, 2005) but in this context, these structured strategies are crucial to the success of the mathematics lessons.

c) Technical (ICT) problems in the case study

While some of the problems required planning and preparation in a pedagogical sense, others were more technical in nature and required technical support and expertise. The following are some of the areas that require consideration.

Firstly, a considerable amount of time can be lost waiting for sites to load. This was especially evident when everyone logged in at the same time. Slow download times were not uncommon at the time of the research (2003) but this is becoming less of an issue in Australia as the Australian education departments and schools put in place infrastructure that supports increased bandwidth and access. Pre-loading the sites before the class helped circumvent that problem.

However, because the nature of the web objects were such, that many were highly interactive, colourful and visual, there were several technical problems. Among the problems encountered in these Web-based lessons were images which were slow to display and applets which did not work because of the absence of Shockwave player. Teachers using the web not only have to know the mathematical content of web sites but also what technical preparation is required. The role of technical support in the installation of appropriate software and to ensure that all necessary hardware works is an important one. As with any technology use, trial runs should be carried out with the web sites concerned to ensure they load properly and that applets are loading easily and can be accessed. Some contingency or alternative web objects should be planned as back-ups in the event a particular web object fails to work. This could be due to various reasons and can include websites being no longer active or in the process of being updated. This unreliability of the technology is one of the reasons why teachers often revert to conventional practices (Cuban, Kirkpatrick, & Peck, 2001; Ensminger, 2008). Technical problems will and do happen even to the best teachers and the sharing of solutions to these problems among the faculty will help prevent more of them occurring.

When considering the web as an effective teaching and learning resource for mathematics, several issues need to be highlighted. The first issue is choosing appropriate web objects that are able to enhance the teaching and learning of mathematics concepts. This includes three aspects:

1. assessing the web object critically to see if it is able to fulfil the requirements espoused in curriculum documents. While mathematical concepts are universally accepted, the emphases and manner in which they are taught varies from country to country. The Australian Curriculum (Australian Curriculum Assessment and Reporting Authority, 2011) places great emphasis on constructive and inquiry based learning and a futures oriented curriculum. This should thus be a consideration in the choice of the web objects,
2. the currency of the web objects and how they might be impacted upon by the ever changing landscape of the web and
3. the level of student control and engagement that can be engendered by this web object.

The second issue pertains to how teachers can develop to meet the pedagogical demands that are thrust upon them in such environments. These include sharing and developing contingency plans for those occasions where technology fails. The third issue is how to circumvent the technical problems that arise before they happen and when they unexpectedly happen. Technical expertise and support from appropriate personnel will help alleviate much of the concerns teachers have. This is an issue that a supportive school management can help address.

Implications for future classroom practice

To use the web effectively for mathematics teaching and learning requires that teachers use appropriate web objects that foster student engagement. There are several types of interactivity and different types of web objects that can potentially be used to engage students, even those who have difficulty with mathematics. However these web objects need to be identified and mapped to existing curriculum for them to be utilised effectively. Professional development for teachers could consider directing teachers to specific web objects that have proven links or direct relevance to a particular mathematics topic or skill. The mathematics department in a school could build their own databases of web objects mapped to the relevant mathematics topics. To ensure success with the use of web resources, some pedagogical skills are necessary. This includes putting in place routine structures such as prepared worksheets, and copying the URLs of specific web pages containing the relevant web objects, ensuring students are able to access the given links easily without having to type in URLs. This can be done in a variety of ways: through a hyperlink on a document, an emailed hyperlink or setting up a wiki that is regularly updated with current work and hyperlinks. Sound pedagogy demands the use of teacher checks to monitor students' online work. This case study showed how teachers can monitor students' work with the interactive web objects using three different methods. These are not meant to be prescriptive and there are other ways to check students' progress on the web. With recent social networking and book marking advances in Web 2.0 several options are available. One effective way would be for students to take screen captures of their work on the web object or applet and paste it in a Word document. This document can then be uploaded onto their own wiki page in the class wiki for later review. The creativity and ingenuity of the teacher will determine how each of these contexts can be set up.

Teaching with the web does not signal the end of classroom management woes. The types of problems encountered can be rather daunting and deter teachers from utilising the web to teach mathematics. However, as this case study showed, by persisting and getting the appropriate technical support, web based lessons can be carried out efficiently and effectively. Students and teachers should give themselves the opportunity to get into a routine of using the web to learn mathematics. Who knows what teachers and students can do once this initial hurdle of unfamiliar territory is overcome?

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