Digital Transformation of High School Education: Microlectures and Instructional Design in Teaching Mathematics

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Abstract
With the rapid development of digital technology nowadays, education and microlecture resources have become increasingly popular and enriched, in accordance with the more personalized needs of diverse schools and students. In high schools, traditional classroom teaching is also undergoing digital transformation. This paper therefore discusses the common features, production procedure and dissemination channels of microlectures. It then demonstrates the design of a modified microlecture-based teaching process, taking the exponential function as a high-school mathematics example. The flexibilities and possibilities of such digital tools for high-school mathematics are also explored, which are followed by the discussion on potential issues that may arise in the classroom, and the impacts of microlecture innovations on students, teachers, and other education stakeholders.
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1. Introduction

With the development of information technologies such as the internet, media and imaging, the digital transformation of education and the sharing of educational resources (Dillenbourg 2016) have been causes for concern following the trends of public education reform and smart teaching innovation. There have been more channels and platforms for students and lifelong learners to study independently and acquire a broad range of knowledge efficiently. Digital education can help learners in a more personalized and exploratory way, complementing conventional classroom teaching and helping educators to better understand their students (Sailer *et al*. 2021). Moreover, this would eventually promote the realization of educational equality and the free dissemination of high-quality educational resources across social classes and countries, which has drawn public attention too. For instance, in 2020, UNESCO published a book named "The Digital Transformation of Education: Connecting Schools, Empowering Learners." Also in 2020, the European Commission released their Digital Education Action Plan (2021-2027), proposing to speed up the transformation of digital education and enlarge the member countries' digital capabilities. In China, the "China Smart Education Blue Book" which was published in 2022, for instance, outlined some of the specific objectives and characteristics of education digitalization. Particularly on the research of high-school teaching and pedagogical methods, Yuan (2023) discussed the ideas and latest trends of the digital transformation in education. Wu *et al*. (2022) compared the digital transformation of education in various countries around the world, whereas in the case of China, rural education and junior teachers should face challenges and difficulties (Cui & Rong 2023). As one of the most appealing elements of educational digitalization (Sweet 2014; olde Scholtenhuis *et al*. 2021), there is no doubt that the introduction of microlectures (or microlessons), as well as microlecture-based teaching is creating new positive energies for students, teachers, and schools. Generally speaking, a microlecture tends to be fast-paced, limited by the short duration of the video. That should require the instructor to use precise and plain language to connect each core knowledge point from textbook contents, explaining each of which clearly and fluently on camera. In the case of high-school mathematics, for example, the new digital teaching, resource integration (and optimization), and interactive instructional design are of great significance and meanwhile, the design approach can be quite flexible (Yuan 2023). Educators need to brainstorm and break through traditional thinking to better explore the new potentials of microlecture-based teaching.

2. Microlecture-Based Teaching for High-School Mathematics

Microlecture resources generally are of small size, so they can be easily utilized in class or uploaded to online resource platforms, providing students with a convenient way to learn. Meanwhile, this would demand educators to meticulously design the lecture, integrating relevant graphics, text, sound, personas, etc. The task of the instructor is to convey relatively abstract and complex mathematical concepts to students in an intuitive and dynamic manner, sparking students' interest in studying mathematics. The teaching load of high school mathematics could be huge, making it impossible to fully satisfy the needs of exercise classes. It is difficult for teachers to cover every question on exercise or exam sheets, which would ignore the individual needs of some students. Nevertheless, the emergence of microlectures would allow teachers to record the explanation process of various problems and conveniently share the videos with students for self-learning. Thus, the design of microlecture-based teaching can help to effectively save time and increase self-learning efficiency, allowing the teachers to better highlight the key or challenging points of the lesson. Below are three common approaches for producing microlectures:

- Real-Life Recording. To produce a realistic microlecture, it often involves recording a self-independent teaching process of the instructor, followed by some necessary video (audio) processing, editing, compression, and exporting of the video content in accordance with the microlecture requirements and quality assurance. This can show students the teaching methodology and style of instructors.
- Screen Recording. Teachers use (professional) screen recording software and equipment on mobile phones, tablets, or computers, in addition to corresponding slides or lecture notes, to record microlecture. In order to highlight and emphasize those high-school mathematics questions, as well as to improve students' attention and enthusiasm in class, teachers can use auxiliary tools such as capacitive stylus pens and writing pads to enrich the microlecture content, along with relevant animations and sound effects.
- Software Recording. Teachers use relatively professional software such as Focusky to add text, annotations, pictures, videos, SWF, sound files, etc. to create MG-animation and microlectures. The requirements for electronic hardware equipment are generally lower, which should help alleviate problems such as blurry images and uninterrupted noises. Professional microlecture software often has its own toolboxes such as mathematical symbols and function editors, as well as relatively rich libraries of scenes, animations and special effects materials. All of these can improve teachers' efficiency, content creation, and written standardization.

2.1 Microlecture Production

Hiring external websites and production teams can improve the professionalism and standardization of the microlecture production, broaden the dissemination channels of microlecture resources, and enhance teachers' competitiveness in those teaching competitions. However, it also requires a large amount of financial support. Relatively speaking, the threshold of basic microlecture production is not too high (for example, by shooting in a micro-classroom), so personal production and team cooperation are feasible even without external professional support. To create quality microlectures, instructors need to prepare and be familiar with the teaching content in advance. For demonstration purposes, the process can be simply designed as follows:

- The photographer needs to first arrange the positions of lights, cameras, microphones, display screens, and other equipment in the micro-classroom. At the same time, the instructor arranges his or her clothes and checks the microphone. To facilitate the production team in the addition of personas into videos, prior to recording, the teacher may deliberately leave the bottom right corner vacant on each presentation slide.
- To achieve cohesive editing and audio control for two video clips (one features the teacher's persona and the other showcases the screen recording of presentation slides), software such as Camtasia Studio, Premiere Pro, and Adobe Audition is recommended, which can help with the editing tasks such as chroma keying for green screen, adjusting the position of the persona (for overall visual appeal), noise reduction on the audio track to enhance the clarity of the instructor's voice, and incorporating video and image elements on demand.
- Having confirmed the video's accuracy with the instructor, the production team can move on to refine and store the video microlecture. It is essential to preserve the source files and materials used in the production process for future re-editing purposes.

2.2 Instructional Design

As far as we are concerned, teachers can utilize microlectures as appropriate in conventional teaching, in order to improve efficiency and clarity. Next, we take the concept and properties of exponential functions as an example, to demonstrate the instructional design of microlecture-based mathematics teaching. Exponential functions are the basis for high school mathematics, which have broad connections with, for instance, logarithmic functions, geometric sequences, probability statistics, and derivatives. They are very important mathematics and statistics tools for studying a large number of real-world and practical applications too. Generally speaking, the learning of exponential functions is built upon the foundation of power functions and basic exponentiation. By integrating some motivating examples, the teachers would be able to cultivate the core competencies of the students in mathematical operations, modeling, and abstraction. In our demonstration of the microlecture-based classroom, the teacher first raises the following two questions related to real life (the second is less simple), guiding the students to contemplate:

Question 1: If the total number of cells is Y and the number of cell divisions is X, what is the mathematical relationship between the two?

Question 2: Suppose the half-life of the element Carbon-14 is 5730 years. If the amount of Carbon-14 is Y (e.g. in micrograms) and the time is X. Do you know the relationship between the two?

Subsequently, the teacher organizes the students to watch a video microlecture and animated demonstration (if available), explaining the background of Question 1. Afterwards, the teacher can derive and write down the exponential relationship between the two variables on the blackboard when X is an integer, such as:

$$X = 0, Y = 2^0 = 1;$$
$$X = 1, Y = 2^1 = 2;$$
$$X = 2, Y = 2^2 = 4;$$
$$X = 3, Y = 2^3 = 8.$$

The teacher proceeds to the other microlecture on the dating of Carbon-14 (i.e. Question 2), explaining the meaning of half-life. The teacher then shows the calculation the element's amount after one year of dating:

$$Y = \left(\frac{1}{2}\right)^{\frac{1}{5730}}.$$

From this, students should be able to figure out the mathematical relationship as follows:

$$Y = \left(\left(\frac{1}{2}\right)^{\frac{1}{5730}}\right)^X, \qquad \text{where } X \in [0, +\infty).$$

On the foundation of the commonalities of the above questions, the teacher should organize a brief discussion among student groups. Next, it is another microlecture on the definition of exponential functions. The teacher summarizes the microlecture and derives the mathematical form of the exponential function $Y = a^X$, where $a > 0$ and $a \neq 1$. During this teaching process, microlectures can not only vividly illustrate exponential functions and related applications, but also save the teacher's time in writing on the blackboard. The teacher can pause the video intermittently anytime, ask questions to the students, and encourage them to think about mathematical questions. In addition to microlectures, the teacher may also use instructional software such as GeoGebra for drawing, simulations, and animated demonstrations. By combining mathematical concepts with visual representations, the teacher can vividly and intuitively illustrate the graphs of exponential functions. This should help the students in comparing the magnitudes of different functions (e.g. between 2.7^3 and 2.7^5, $0.6^{-0.1}$ and $0.6^{-0.2}$), reinforcing their understanding of the core concepts in the textbook, mathematical properties, and extended knowledge (e.g. the monotonicity of the exponential functions in class).

As a common practice, before class, teachers can release microlecture resources for students to preview prerequisites. In class, teachers use microlectures to assist in face-to-face classroom teaching. After class, teachers release slides, lesson materials and extended microlecture resources to help students review and consolidate the relevant knowledge points. Therefore, the entire instructional design should merge teacher-led instruction with students' self-learning, leveraging the unique advantages of digital technology (high flexibility, abundant resources, splendid visual effects, strong interactivity, etc.). It aligns with the constructivist teaching philosophy (i.e. inquiry-based method of teaching) of combining "teacher guidance" with "student-centered learning". Specifically, based on the teacher-led instruction, supported by microlectures, extra efforts are made to emphasize the active and positive role of students, enhancing their initiative and enthusiasm for learning. The American educational psychologist David Ausubel first proposed that meaningful learning is a process of assimilating new knowledge into existing cognitive structures. In this case, the exponential functions and power functions are related concepts in this case, where there is a close connection in mathematics. In the classroom, by introducing real-world examples from selected microlectures, teachers can better encourage students to discover and contemplate the exponential function concept and corresponding properties. That also facilitates the comparison and assimilation of the two mathematical definitions (i.e. exponential and power functions). The students would learn how to deduce equations, summarize patterns, and purposefully explore the correlations between the two, all of which can make their learning experience meaningful.

3. Discussion

Breaking through the boundaries of traditional textbooks, the digital transformation of education brings about a diversity of (and often international) views and discussions. It however has to be supported by new-generation artificial intelligence and recommender system algorithms to legitimately and reasonably mine big data, in order to persistently organize, filter and refine gigantic information. This is to provide personalized and tailor-made services for diverse groups of teachers and students with distinct characteristics. The significance of microlecture-based teaching lies in better guiding students to quickly gain new domain knowledge, extend their cognitive perspectives, and cultivate their abilities for independent or reinforced learning. Firstly, it not only provides abundant resources for students at different academic levels, but also helps to achieve educational equity and a more balanced allocation of educational resources between countries, regions, and social classes, thus narrowing the education gaps and information asymmetry. Secondly, the emergence of microlectures has enormous potential to generate high-quality teaching resources for educators and speed up the update of knowledge systems. This contributes to the development of the teachers' skills and proficiency. Additionally, these digital resources can be strong support for teaching research and optimization of instructional design, helping to enhance teachers' abilities to manage classrooms and understand classroom dynamics. Thirdly, for schools, the merge of microlectures and smart teaching enhances the flexibility and innovativeness of classroom teaching organization, benefiting the integrated education, the digital transformation of teaching, the construction of digital teaching platforms, and the inter-school collaborative exchanges.

However, the popularization of microlectures and digital education has to encounter several challenges in the teaching of high-school mathematics. It is difficult to guarantee the self-motivation, self-discipline, and learning effects of high school students in general. Therefore, their parents could tend to trust traditional classroom teaching more. Therefore, during the process of digital teaching such as microlectures, the students should learn to reflect on and make customized plans tailored to their individual needs and objectives. The students can also communicate their thoughts and opinions with classmates and the school on a regular basis, in case there are misjudgements. Meanwhile, some mathematics educators have more traditional mindsets regarding teaching, who probably have limited experience in digital education and microlecture use. Compared to microlectures, they would prefer blackboard writing and assignments, with a focus on textbooks and exercise training. Consequently, they may not be very supportive of digital technology and tools. Even when they use microlectures, it can merely be a simple playback of videos in the classroom, and they eventually fail to fully leverage the optimized and smart teaching functions of microlectures. Hence, to promote digital education, a shift in the schools' teaching philosophy and necessary digital training for teachers is absolutely essential. The teachers have to learn how to integrate appropriate digital elements with high-school mathematics thinking in their daily teaching activities. Furthermore, the production of microlectures has put forward higher requirements on the digital software and hardware of high schools, as well as the capabilities of the technical personnel, particularly for developing countries and regions. Not only are there urgent needs for professional recording facilities and tools, but the data storage, processing of microlectures, and subscription to academic software and equipment also require time and financial investment. Different schools and educators have varying perspectives and attitudes towards the digital transformation of education, which can easily exacerbate the information disparities, digital divide, and educational imbalances. Fundamentally, addressing these issues necessitates not only the involvement of the schools themselves but also the support of the student communities, parents, societies, and education regulators.

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