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Title	Impact of a hand-held wireless electronic device (eduPAD) on science and mathematics teaching-learning environment
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Source	<i>Journal of Science and Mathematics Education in Southeast Asia</i> , XXIV(2), 51-66

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**IMPACT OF A HAND-HELD WIRELESS  
ELECTRONIC DEVICE (EDUPAD) ON  
SCIENCE AND MATHEMATICS  
TEACHING-LEARNING  
ENVIRONMENT**

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*The Ministry of Education, Singapore has undertaken a number of initiatives to make the learning process in schools more student-centered. A proto-type electronic learning device was developed and tested in an authentic school setting. This paper reports the impact of the introduction of the electronic device on the teaching and learning of science and mathematics in the trial school. For this purpose, science and mathematics lessons were video-recorded prior to the introduction of eduPAD and with the use of eduPAD. The video-recorded lessons were analysed to determine the degree of shift from a teacher-centered approach to a more student-centred approach. Are there more student-centered activities than before? Are teachers comfortable using eduPAD as a tool to help them in the teaching process? Are students happy to use the device for self-directed independent learning? These are some of the questions that this paper has addressed.*

**INTRODUCTION**

The advances in the Information and Communication Technology have enabled the creation of learning environments that provide meaningful and challenging exploration as well as independence in learning. For example, a teacher can now provide a computer-based learning environment, where the students take the active-independent initiating role in learning, while the teacher takes a coach-support facilitating role (Duffy & Jonassen, 1992; Perkins, 1991). Also, research studies indicate that when students interact

with the computers they become inquisitive and creative with an increase in their level of intrinsic motivation as a result of acquisition of the freedom to take over their own learning (Armour-Thomas, White, & Boehm 1987; Gatto, 1993, Lehman, 1994; Maor & Fraser, 1994; Wang & Sleemen, 1994).

The problem faced by schools in providing computer-based learning is the lack of access to computer facilities in the schools. Currently in schools computer labs / rooms are set up with twenty odd computers in each room, to provide some experiences in computer-based learning. Moreover, students have access to these computers only when the teachers taken them to these rooms. This is clearly an inadequate provision for effective computer-based learning environment. To overcome this problem of poor computer-student ration and station-based computer usage in schools the Ministry of Education, Singapore under its Master-plan for IT in education initiated a project to develop a proto-type hand-held wireless computer which is inexpensive so that all students can have one each and use it on an anywhere-anytime basis. It was envisaged that this hand-on classroom tool with the ability to access the networks would be a motivator for students to actively engage in learning and that its use could encourage the kind of independence and autonomy that many educators agree is important for students to achieve in their learning.

Wireless networks are no longer strictly experimental. Schools and colleges in the United States of America and the United Kingdom are going into the wireless technology in big ways with the expectation that the networks will enhance teaching, learning and research. Wireless networks are also well suited to collaborative learning. For example, students anywhere on campus can form small learning groups online to tackle any learning task / problem (Olsen, 2000).

## THE EDUPAD PROJECT

The development and testing of the proto-type electronic device in a trial school was an inter-agency collaborative project involving a number of institutions in Singapore. The Ministry's industrial partners were mainly responsible for the development of the hardware device and the software applications for the device. The Educational Technology Division of the Ministry of Education was in-charge of the training and exploration of the use of the eduPAD system in the trial school. The National Institute of Education was invited to evaluate the pedagogical use of the eduPAD in the classrooms.

## THE EDUPAD DEVICE

The eduPAD weighs about 800 grams. It has an 18-cm (diagonal) VGA LCD colour display panel combined with a built-in microphone and speaker (Figure 1). It works on a rechargeable battery, which lasts up to six hours. The method of input incorporates both the Stylus and Virtual Keyboard. In addition to the eduPAD's resident memory of 16 MB, the device provides interfacing slots to data storage cards. The school subject textbooks have been converted to eduBOOK. eduBOOK brings textbooks to the students via a digitized format, incorporating hypermedia features to help students search for information and enhance their understanding of concepts by animations and audio effects. Inserting the eduBOOK chips into one of the interfacing slots in the eduPAD students can access information from the eduBOOK.

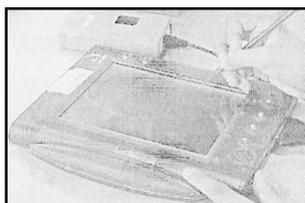


Figure 1: The eduPAD device

**HOW THE EDUPAD SYSTEM WORKS**

Figure 2 illustrates the set up of the system in the school. Teachers can use the system to create and carry out class activities. For example, teachers can prepare assignments (e.g. worksheets & quizzes) using a PC in the staff room that has been installed with the Teacher’s Management Tool (TMT) software.

These files can be saved onto the eduPAD server via the school’s existing local area network (LAN) system. They can then be sent through the Classroom Management Tool (CMT) to the pupil’s eduPAD during the teacher’s lesson or they can be saved as files that students could download through the Homework Tray of the pupil’s eduPAD. In the latter case, the students would be alerted of the files in the Homework Tray for downloading through the e-mail.

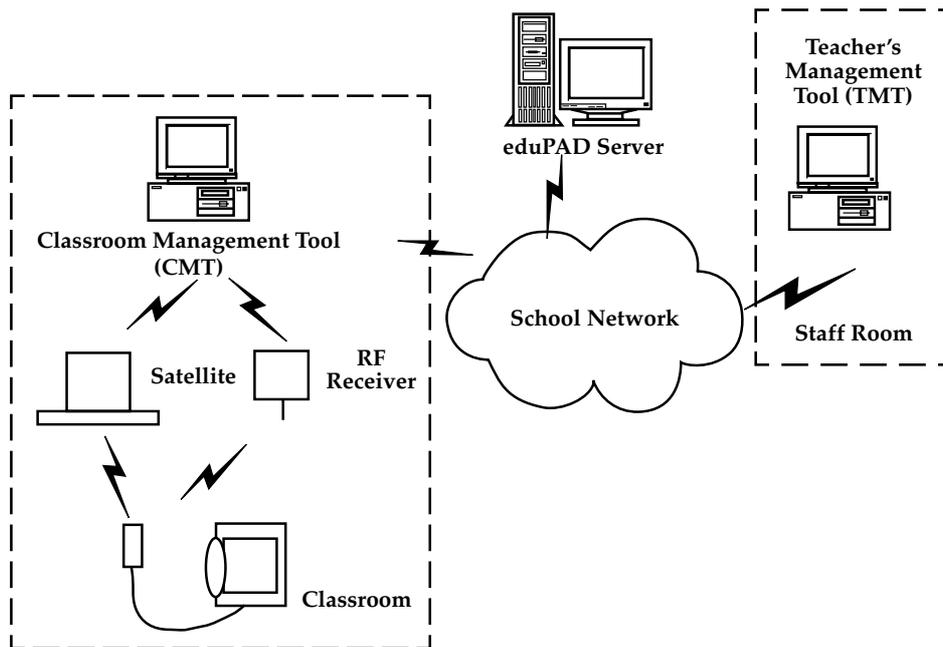


Figure 2: The eduPAD System in the school. [Source: KRDL, MOE (ETD)]

When the teacher walks into the classroom, he can download his files onto the classroom PC that has been installed with the Classroom Management Tool (CMT) software. With a click of a mouse button the assignment files are beamed to the students' eduPADs via diffused infrared satellites mounted on the ceiling of the classroom. Alternatively, the students would have downloaded their assignment from the server through the Homework Tray before the lesson and the teacher merely gets the pupils to do the assignment.

Pupils submit their completed assignments through the wireless using radio frequency waves. A radio frequency receiver mounted on the ceiling picks up the data from the eduPADs and channels them to the CMT for auto marking and collation of results. A copy of the data is also automatically sent to the eduPAD server. The teacher is thus able to get instant feedback on the performance of the students. Pupils on the other hand can use the device as a platform for their work, on which they can carry out hands-on and collaborative activities. In addition, pupils can use the eduPAD to plan and organise their timetable, set up a task list to prioritise their work, take notes, e-mail their peers and access the Internet and the eduBOOK to source for information.

### THE RESEARCH ISSUE

As an IT communication tool, eduPAD offers tremendous pedagogic potential for learning both in the classroom and at home. Access to the Internet expands classroom resources for learning science and mathematics dramatically by making many resources from all over the world available to students. It brings information, data and images into the classroom from place otherwise impossible to access and it does this instantly. However, the exact nature of what constitutes the best pedagogic practice for optimizing the use of eduPAD in the classroom is the key research question that this whole project hopes to answer. Basically for this initiative to be successful there has to be some change in the teaching-learning milieu in the schools. The fundamental shift that will be required is a shift from the teacher-centred examination oriented education to learned-centred holistic education. This initiative calls for skilled and sensitive teaching that is carefully planned. It demands that teachers change the ways that they relate to their students and students change the way they regard their own learning in radical ways. It is hoped that eduPAD would help shift a teacher's mindset about learning from a receptive to a constructive paradigm and thus make them feel comfortable in a coach-support-facilitator role.

The report of the investigation of the change in teaching approach as a result of the use of eduPAD device in the classroom can be found in other studies. This paper reports on the finding related to science and mathematics teaching.

### METHODOLOGY

In 1994 Stigler started the use of videotaped lessons to study and understand teaching that goes on in classroom. To investigate the change in the learning climate there is the need to look at what actually happens in the classroom and that is where videotape comes in handy. It reveals exactly what teachers say and do and how students respond. In "The Teaching Gap," Stigler and Hiebert (1997) advocate using video for what they call "lesson study." This strategy was employed by us to get thumbnail sketches of teachers teaching Science and Mathematics to Secondary 1 classes at a secondary school in Singapore. Video recordings of lessons taught by the teachers were made prior to the introduction of eduPAD device and with the use of the device at the initial and final stage of the trial. The pre-eduPAD lessons were

recorded in January - February 2000. They formed the baseline data for comparison. The eduPAD lessons were recorded in July - October 2000. The videotaped lessons were recorded analysed using an episode-time analysis observation form devised by the researchers. The main episodes recorded related to teacher initiated and student initiated events in the lesson. In this manner a picture of the dynamics of the lessons was captured. After the analysis of the videotaped lessons comparison was made between the baseline pre-eduPAD lesson data with the eduPAD lesson data to determine the shift in the way the teachers conducted the lessons with the use of the eduPAD. At the end of the trial focus group interviews were conducted to get the views of the teachers and students. A questionnaire was also administered to get students' perception of the eduPAD.

### **COMPARISON OF EDUPAD SCIENCE LESSONS WITH NON-EDU PAD SCIENCE LESSONS**

To highlight the similarities and differences between the lessons, the sequence of episodes in the science and mathematics lessons are tabulated in Tables 1, and 2 respectively. From the description of the science lessons in Table 1 it is obvious that there are both similarities and differences in the structure of the three lessons. In the non-eduPAD lesson the teacher plays the central role in directing learning through direct teaching using mainly the Question-Response-Elaboration (QRE) approach. In the eduPAD lesson 1 and 2 the students were engaged in individual and group work for about 50% of the lesson time. The teacher acted as a facilitator for learning to take place. The teacher integrated the texts in the eduBOOK into her lesson and used them as resources for the individual and group activity.

Table 1  
*Comparison of pre-eduPAD and eduPAD science lessons*

Time	Non-eduPAD Lesson	Time	Non-eduPAD Lesson 1	Time	Non-eduPAD Lesson 2
Start of Lesson	Teacher explains the correct technique of reading volume in measuring cylinder. Students engaged in lesson through QRE recitation technique.	Start of Lesson	Teacher explains the use of dichotomous keys to classify organisms. Uses two examples, one of that is from the eduBOOK.	Start of Lesson	Teacher reviewed with the class simple machines-levers using the QRE technique.
7.05 min	Teacher discusses volume of regular objects - formulae.	4.05 min	Students are engaged in individual seatwork using eduBOOK.	2.40 min	Teacher then directed the pupils to turn to turn to page 261 of their eduBOOKs that showed animated pictures of lever systems. Teacher discussed which system produced which system produced the better turning effect with the class using QRE.
11.00 min	Teacher discusses how to find volume of irregular objects - immersion and use of displacement can.	9.10 min	Teacher checks on exercise using recitation technique.		
19.10 min	Teacher discusses how the volume of an irregular-floating object may be determined.	12.30 min	Students are engaged in collaborative group work using information from the eduBOOK to develop a chart to classify vertebrates using dichotomous keys.	7.55 min	Teacher instructed class to scroll down to page 267 to the "Think Tank" section and attempt Question 4A and B.
23.30 min	Teacher consolidates the lesson by reviewing the main points.			11.55 min	Teacher checked the answer and the working through questioning.
27.00 min	Lesson ended	21.15 min	Group leaders present work to class. Class and teacher provide feedback to the group.	13.50 min	Teacher repeated the process with Question 4C.
		28.00 min	Lesson ended.	17.00 min	Lesson ended (teacher distributed worksheets for pupils to do at home)

All three started with the whole-class-direct teaching approach where the teacher taught a concept or skill using examples and kept the students on focus by questioning them continuously about what she was teaching. This led to further class discussion on the focus issues of the lesson – finding the volume of irregular and floating objects in the non-eduPAD lesson whereas in the eduPAD lessons students were engaged in individual and group work – use of dichotomous keys for classification (eduPAD lesson 1) and lever systems (eduPAD, lesson 2). The difference may be due to the introduction of the eduPAD device, which indirectly required the teacher to plan learning activities incorporating the device into the lessons. This made the lesson to be more student-centered than the non-eduPAD lesson.

The students were certainly more directly involved in the learning process in the eduPAD lessons through independent seatwork and collaborative group work. During the group work there was spirited interaction among group members. They discussed and exchanged ideas with the aim of completing the assigned task.

The main eduPAD system feature used by the science teacher was the eduBOOK. The exercises and the enhancement features of the eduBOOK seemed to be valued by the teacher to help her design learning activities.

### **COMPARISON OF EDUPAD MATHEMATICS LESSONS WITH NON-EDUPAD MATHEMATICS LESSON**

Table 2 displays the flow of mathematics lessons. In the non-eduPAD lesson the teacher used the classical input-exercise-output model of teaching mathematics. The lesson began with the teacher explaining a mathematical concept using examples familiar to students. The teacher then gave an exercise for students to do in order to assess their level of understanding. The teacher checked students' work and provided feedback. Teacher discussed three other problems with the class and provided seatwork to reinforce the concept. Teacher checked seatwork and set homework to further reinforce the learning. This lesson had the pattern of frontal teaching (about 38% of lesson time) followed by practice (about 26% of class time) and feedback from the teacher (about 20% of lesson time).

The first eduPAD lesson followed the same pattern as the non-eduPAD lesson during the first half of the lesson. The second half of the lesson

engaged pupils in exploring the Internet to find information about the different types of polygons. Students faced difficulty in getting the connection. The teacher instructed the class to complete the task in the school computer lab. This lesson involved 43% of class time in direct teaching and the rest of the class time was used in trying to get link to websites.

The second eduPAD lesson exhibited the use of two features of the eduPAD system. The lesson started with a pre-test on the topic of the day. (Some students had difficulty in retrieving and submitting the test). It was followed by a group activity that required the students to connect to the Internet and find information about the properties of different types of quadrilaterals. Most of the students were not able to get the connection to the Internet. The information that was gathered by some students formed the basis for class discussion that followed. In this lesson students utilized roughly 45% of the class time to retrieve, complete and submit the pre-test. They were engaged in exploring the Internet for about 40% of class time and class discussion with teacher for 15% of class time.

In both the eduPAD lessons the teacher tried to introduce the features of the eduPAD device to make the lesson student-centred but the technical difficulties encountered during the lesson hampered the smooth flow of the lesson. A lot of class time was wasted in trying to link to the Internet. If the technical problems had not hampered the flow of the lesson, the eduPAD lessons would have been good examples of lessons where students are engaged in information seeking and construction of knowledge on their own under the guidance of the teacher.

Table 2  
*Comparison of non-eduPAD and eduPAD mathematics lessons*

Time	Pre-eduPAD Lesson	Time	Pre-eduPAD Lesson 1	Time	Pre-eduPAD Lesson 2
Start of lesson	Teacher started the lesson by explaining the concept "number sequence" using the reproduction pattern of a pair of pet rabbits. The sequence was illustrated on a OHP transparency. Students listened to the teacher and followed the sequence in the increase of the offspring.	Start of lesson	Teacher introduced the topic of the lesson "Angle properties of polygons" and discussed the names and properties of polygons.	Start of lesson	Teacher recapitulated the last lesson and introduced the topic of today's lesson "Quadrilaterals."
		7.00 min	Teacher tested the students to see whether the class could recall the names and properties of polygons.	2.38 min	Teacher then briefed the class about the work plan of today's lesson. Specific tasks were assigned to each work group in the class.
8.30 min	A problem was set for students to work out. Students worked on the problem.	9.00 min	Teacher then discussed with the class the properties of triangles in terms of length of side and size of angle and tested pupils' understanding.		Students were instructed to go to the "Homework" tray, retrieve the Pre-test, do it and submit to the teacher's control station using their eduPAD. Most of them were able to do but some faced difficulty in the assignment.
11.00 min	Teacher discussed the problem with the class. Students responded to teacher's questions and identified the pattern of increase.	14.30 min	Teacher showed how to construct a triangle given the length of sides on the OHP.	25.00 min	Teacher helped students who were still having problems to retrieve or submit the pre-test by sending the test directly to the students.
13.30	Teacher discussed three other problems with the class. Students were involved in identifying the pattern in the number sequences.	19.30	Teacher gave seatwork for pupils to construct a triangle using their compasses and measured one of its angles.		Teacher instructed the other students to go to the internet and search for information about the properties of the different types of quadrilaterals.
16.20 min	Teacher set seatwork exercise. Students worked on the problems.	25.00 min	Teacher checked pupils' work and answers.		Students made attempt to get information from websites but many of them encountered difficulty in getting a connection.
19.35 min	Teacher discussed the problems with the class. Students responded to teacher's question and explained how they arrived at the answer.	26.30 min	Teacher instructed the class to connect to the internet using their eduPAD and find out all about triangles. Pupils attempted to get the connection but failed.		

Time	Pre-eduPAD Lesson	Time	Pre-eduPAD Lesson 1	Time	Pre-eduPAD Lesson 2
21.30 min	Teacher asked the class to attempt Exercise No. 2 from the textbook. Students worked on the exercise.	34.00 min	One student managed to get into the link. He shared the website address with the class.	48.00 min	Teacher discussed the properties of the different types of quadrilaterals based on the information provided by the students.
23.40 min	Teacher discussed the exercise with the class. Students respond to teacher's questions and explain their work strategy.	42.00 min	Two more students managed to get into the link but the rest of the class had problems to get into the link. The teacher provided a few website addresses for pupils to try for themselves.		(Students who succeeded in their attempt to log on to the internet responded to teacher's questions)
25.00 min	Teacher assigned homework (Ex. 3 and 4) and gave instruction of what is expected. Students noted the homework task.	59.30 min	Most of the pupils were still not able to get to the connection. The teacher instructed the class to copy down the website addresses and to try to enter the internet at the school computer lab and complete the task.		The teacher jotted the main points on the whiteboard. Students copied the notes from the white board.
30.00 min	Lesson ended.			56.00 min	Lesson ended.
		61.00 min	Lesson ended.		

**TEACHERS' EVALUATION OF THE EDUPAD SYSTEM**

The focus-group interview at the end of the trial period revealed that in general the teachers were positive about the use of an electronic device to enhance pupil learning by making them more responsible for their own learning. But they were concerned about the technical problems encountered in the use of the device. With the present device they felt that a lot of class time was wasted in attending to technical problems. This resulted in frustration both for the students and the teacher.

The use of the Internet to source for information was viewed positively by the teachers. Some teachers reported that students when they were able to get access to the Internet were able to come out with useful information pertinent to the topic of the lesson. But with the present device, Internet access was very limited to students as access was possible only in the

classroom and in the library. During the lessons the students had difficulty in accessing the Internet due to technical problems, when 40 odd students tried to access the Internet at the same time. Some students as a result of the initiated Internet activity in the classroom went home and used their home computer to continue their search. Generally, teachers reported that the ability to browse the Internet was a useful feature as browsing on the Internet enabled the pupils to go beyond the textbook to the global resources and read real authentic reports. This they said could enhance the spirit of self-learning and life-long learning.

Most teachers expressed the view that if the CMT system worked properly then it would be a very useful feature for the teacher. The teachers could prepare quizzes, worksheets and assignments for use in the classroom. The mathematics teacher reported that she was able to monitor her students' progress in her subject by conducting pre- and post-tests for her lessons. Using the analysis of result feature she was able to identify the weaknesses, misconceptions and individual difference in level and rate of mastery of content of her students.

Some teachers found the resources in the eduBOOK of their respective subject useful in planning their lessons, especially the enhancement features of the eduBOOK like the animation, sound effects and hyperlinks. These features helped them to illustrate some of the abstract concepts more meaningfully.

### **STUDENT EVALUATION OF EDUPAD**

A questionnaire was administered to the students who were involved in the trial to obtain feedback from them. A total of 116 pupils responded to the questionnaire. In addition, two foci group discussions were held. Twenty students selected by their respective Form teachers joined the discussion sessions, ten students per group.

The students were generally optimistic about the potential benefits that could be brought about by this eduPAD. When asked whether they would like to continue to use the wireless handheld devices similar to the eduPAD, 72% said they would. Of the 116 pupils who responded to the questionnaire, 53% agreed or strongly agreed that "classroom lessons were more interesting when eduPAD was used", and 40% agreed or strongly agreed that they

were “eager to learn when eduPAD was used in class”. When asked what has made eduPAD lessons more interesting, the pupils often mentioned the incorporation of multimedia features into the eduBOOK, getting immediate feedback from teacher and the use of Internet to search for more information during the interview.

From this it is evident that the incorporation of multimedia features into the eduBOOK aroused the students’ interests in learning. In the survey, a good percentage of the pupils agreed or strongly agreed that multimedia features made information displayed in eduBOOK more interesting (72%) and 52% felt that they helped them to understand the concepts introduced better.

However 46.5% students disagreed or strongly disagreed that “classrooms lessons were more interesting when eduPAD was used.” It appears that negative feelings resulted mostly from the problems encountered when accessing for the information. The students complained that the system often “hangs” and this interrupted their learning, there are too many chips for each eduBOOK, which they had to change often and the loading time was slow.

An overwhelmingly big percentage of students (74%) thought that accessing the Internet during lessons helped them to learn. The students believed that “WWW” provided additional information not available in the textbooks and such information helped them to understand the concepts covered. Another advantage of using Internet mentioned by the students was that Internet helped them to do research. It appeared that some students revisited the same sites again outside the classroom.

## CONCLUSION

The six-videotaped lessons reviewed indicated that the degree of frontal teaching in the science and mathematics lessons was less in the eduPAD lessons where the teachers tried to incorporate the learning facilities of the eduPAD device. The eduBOOK and the Internet link were the features that teachers favoured most. Through the use of these features the teachers planned learning activities that involved individual seatwork or cooperative group work. Students showed enthusiasm in the lessons with eduPAD. However, in some instances the students were not successful in carrying out the planned activities using the devices as they faced technical problems.

The interview with the teachers confirmed some of the shortcomings of the device. Though the teachers were positive about the use of a device like eduPAD to enhance student learning they were emphatic that all the technical problems associated with the use of electronic devices need to be carefully examined and rectified. In particular they found getting access to the Internet difficult when a whole class of pupils were trying to get access into the Internet.

The students on the whole were optimistic about the potential benefits that could be brought about by the use of the eduPAD. In particular they found the access to the Internet and the enhancements in the eduBOOK as useful features to help them get a better understanding of the subject content. Negative views expressed towards the use of the eduPAD were mainly related to the technical limitation of the proto-type device. Nearly 75% of the students expressed a desire to use a device as a learning enhancement tool.

On the whole it can be said that the eduPAD device has the general features and potential to engage pupils in independent and collaborative work but has to be made more versatile, reliable and interactive if it is to function as a teaching-learning tool in the classroom setting. As it is, it can function as a device for self-directed learning and for communicating with peers. Even this aspect has limitation, as the device cannot be use outside the classroom except for reading the content of the eduBOOK and non-interactive tasks.

The use of an improved version of the device with greater access to the Internet and interactivity could lead to a greater likelihood of teaching becoming more student-centered not only in science and mathematics classes but in classes for the other subjects. Also, it could lead to the achievement of the major objective of education, that is, to empower the learners to become more independent in the learning process so that they can develop the attitude and skills for lifelong learning.

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