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Students' Perceptions and Behaviour in Technology-Rich Classroom and Multi-Media Classroom

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ABSTRACT
Kurt Lewin proposed the field theory which stated that our behaviour was a result of both our personality and our environment. Based on this theory, it could be deduced that teacher's teaching behavior was a result of both teacher's personality and classroom environment. Considering the challenges of pedagogy transformation and the modest use of technologies in classroom, we hypothesize that designing and using technology-rich classroom (TRC) is one of the methods for changing the classroom from teacher-centered learning to more student-centered learning that encompasses replacing lectures with active learning, integrating self-paced learning programs and/or cooperative group situations, ultimately holding the student responsible for his own advances. In order to test our hypotheses, a TRC was designed according to the adapted SMATE model, and the differences of students' perceptions, learning and teaching behaviour in TRC and in multi-media classroom (MMC) were analyzed. SMATE model referred to the framework for equipping classroom, including showing content, managing facilitates, accessing technologies, tracking process, and enhancing learning. We conducted an experimental research in a primary school with 143 students from 4 classes. The experimental group comprised of two classes in a TRC environment. The environment was equipped with Wi-Fi, wireless display, dual screens, and site facilitators. Additionally, an iPad was made available for every student in the class. The other two classes were the control group and had a MMC environment, in which a computer and a projector were equipped. The experiment lasted for one full semester with 12 weeks. The results indicated that the scores of students' perceptions in TRC were significantly higher than scores in MMC, and students spend more time engaged in individual learning and collaborative learning in the TRC than in the MMC.
Keywords: technology-rich classroom, multi-media classroom, learning environment, learning behaviour, student-centered

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State of the literature

- Previous research on classroom environments indicated that the physical arrangement affected teaching and learning behavior.
- The design and development of the next generation learning space became a hot research area to promote educational innovation through technology integration.

Contribution of this paper to the literature

- The adapted SMATE model could be used as a framework for designing technology-rich classroom environment.
- Wireless display and shared screens for students in classroom were crucial for sharing learning outcomes and promoting interaction.
- Pedagogy fitness for the TRC is another critical factor, and teachers should develop different pedagogies in newly developed TRCs.

INTRODUCTION

With the development of ICT in education and considering scaling up the innovation of technology enhanced learning, researchers begun to conceptualize how learning environments can be made more effective, efficient, and engaging on a large and sustainable scale (Spector, 2014). The terms of next generation learning space, smart learning environment, and smart classroom emerged. Learning space is a new emerging research area, with the aim to promote independent, flexible, and engaged learning by providing leaner appropriate technology and pedagogy (Huang, Hu, and Yang, 2015). Smart learning environments (SLEs) are defined as physical environments that are enriched with digital, context-aware and adaptive devices, to promote better and faster learning (Koper, 2014). With technology support, smart classrooms become places where teachers and students could practice rich and immersive teaching and learning experiences that they have never experienced before (Li, Kong, and Chen, 2015).

The design and development of the next generation learning space or smart learning environment became a hot research area to promote educational innovation through technology integration. A Technology-rich classroom (TRC) is believed to be one of the most important learning spaces in formal learning environments, and is one of the most dominant research in smart learning environments. In this paper, TRC is equipped with technologies for both teachers and students, such as tablets, multi-screens, wireless display, etc. to promote easy and engaged learning. In comparison with TRC, the multi-media classroom (MMC) is defined as a normal classroom equipped with a computer and a projector screen to be utilized by the teacher.

Since the late 1960s, classroom environment has been established as an active field of research in the conceptualization, assessment, and study of perceptions of psychosocial aspects of school classroom learning environments (Fisher and Fraser, 1983). A striking feature of classroom environment research is the availability of a variety of economical, valid and

widely-applicable questionnaires that have been developed and used for assessing students' perceptions of classroom environment (Fraser, 1998). After technology introduced into classroom, much of this research has focused on the effect of computer usage on student attitude, social outcomes, motivation and interest (Dorman and Fraser, 2008). Some studies have investigated the psychosocial environment of classrooms employing technology through validated questionnaires, like New Classroom Environment Inventory (Newhouse, 2001), Technology-rich Outcome focused Learning Environment Inventory (Aldridge and Fraser, 2004), Technology Integrated Classroom Inventory (Wu, Chang, and Guo, 2009), and Classroom Environment Evaluation Scale (Yang and Huang, 2015), etc. Another commonly used method for technology-rich classroom environment research was classroom observation based on observation tools (Vaughn, 2011; Bielefeldt, 2012; Conner, 2013; Elmendorf and Song, 2015; Liang, 2015 ;). The two research methods of inventory and observation could be used together to validate each other's results, while few mixed research was found in technology-rich classroom environment research.

On the other hand, with emerging technology integrated in classroom, researchers developed and discussed visions of potential learning environments with a focus on how digital technologies could facilitate or even enable practices of learning (Sutherland and Fischer, 2014). Various technologies, like multimedia communicational supporting platform (Shi et al., 2003), Ambient intelligence (Augusto, 2009), teacher-designed website (Chandra and Fisher, 2009), Interactive White Board (Manny-ikan, Tikochinski, & Zorman, 2011), etc. were developed or used in physical classroom or virtual classroom. Huang et al., (2012) defined smart classroom as the a physical classroom space that was effective for showing teaching content, convenient for accessing digital learning resources, easy for instructional interaction, well-situated for classroom management, with contextual awareness. Since then, researchers have been engaged in developing theoretical models, formulating a common terminology, providing easy-to-use tools for smart classroom. Kim (2012) implemented a smart classroom information display system with 13.56MHz RFID (Radio-frequency identification), in order to identify and distinguish individual users and to provide various services to the users. Lui and Slotta (2014) presented the design of an immersive simulation and inquiry activity for technology-enhanced classrooms, and showed that immersive simulations engaged students, helped them to establish and build upon ideas about evolution in biology, and encouraged learning of challenging biological concepts. Shen, Wu and Li (2014) developed a smart classroom system that integrates near field communication (NFC) technology to automate attendance management, locate students, and provide real-time student feedback. While many similar smart classrooms or TRCs were built and used globally, only few formal studies have been reported on how these TRCs are used by teachers and students (Wilson and Randall, 2012).

Brooks (2012) pointed out that classrooms shape instructor behavior and activities, and instructor behavior and classroom activities shape on-task student behavior. Thus, students' and teachers' behavior in TRCs should be different from the behavior in MMCs. Field theory

states that our behavior is a result of both our personality and our environment (Lewin, 1939). Based on this theory, it could be deduced that teacher's teaching behavior was a result of both teacher's personality and classroom environment. Therefore, we hypothesize that designing and using TRCs is one of the methods for changing teacher's teaching behavior or pedagogy adoption in classroom.

Chinese Ministry of Education (MOE) has launched the "Curriculum Reform Outline in Basic Education (Pilot)" in 2001 (MOE, 2001), which emphasized self-regulated learning, inquiry learning, and collaborative learning in classroom. However, after all these years, the learning pattern in classrooms is still teacher-centered (Huang and Yang, 2014). Thus, the aim of this study is to discover how to build TRCs for transforming learning patterns to a more student-centered learning in physical classrooms. The research questions were (1) what are the differences of students' perceptions of technology-rich classroom (TRC) environment and their perceptions of multi-media classroom (MMC) environment? (2) What are the differences of students' learning behavior in a TRC and a MMC? (3) What are the differences of teaching behavior in a TRC and a MMC? The basic aim of mathematics education was described as "to bring mathematical knowledge and skills that are required by daily life to the individual, to teach students problem solving and to bring them a way of thinking that handles incidents including a problem-solving approach". For this reason, problem-solving skills take an important place among mathematical skills (Baykul, 2004; De Corte, 2004). Indeed, Nation Council of Teachers of Mathematics (NCTM) standards also indicate that problem-solving skills have higher priority in teaching mathematics.

METHODS

In order to understand the differences of students' perceptions and behaviours in TRC and MMC, and to find the ways to change classrooms to a more student-centered learning place, we followed a co-design method, where the TRC was designed through the close collaboration of researchers, technology experts, site facilitators and teachers. SMATE model (Yang and Huang, 2015) was adapted to design the TRC in this research, as shown in **Figure 1**.

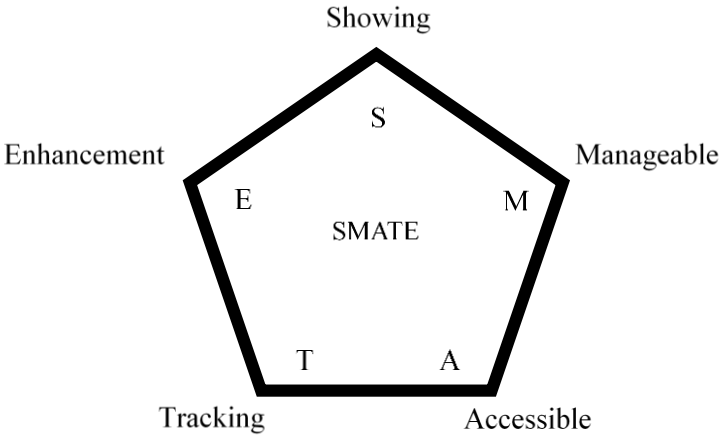

Figure 1. SMATE model for designing technology-rich classroom environments

Showing emphasized on the technologies used to promote the presentation of instructional contents from the teacher or learning outcomes from the students, and a dual screen was equipped for this purpose. *Manageable* emphasized on the flexibility of facilities to conduct various learning activities, such as whether the layout was suitable for both collaborative learning and didactic pedagogy. *Accessible* emphasized on the convenience for utilizing and sharing digital learning resources in the classroom, including the access to the Internet. For this purpose, the classrooms were equipped with Wi-Fi, iTeach (a teaching and learning platform for iPads) and one iPad for each student; iTeach is a classroom teaching platform specially designed to motivate interaction between teachers and students. Through iTeach, teachers could send learning materials to students' iPads and also collect students' responses to questions in real time. *Tracking* emphasized on the intelligent control of temperature, lighting, noisy, electricity, etc.. For example, the temperature adjust automatically for a better learning experience. *Enhancement* emphasized on methods to promote technology integration in teaching and learning. A site facilitator was made available during this study to help teachers develop technology integration pedagogies.

In the MMC environment used in this study, a computer and a projector were equipped, to allow teachers to project their slides or contents from the Internet on the screen. While in the TRC, WiFi, 1 iPad for every student, wireless display, iTeach, and site facilitators were equipped, as shown in **Figure 2**.

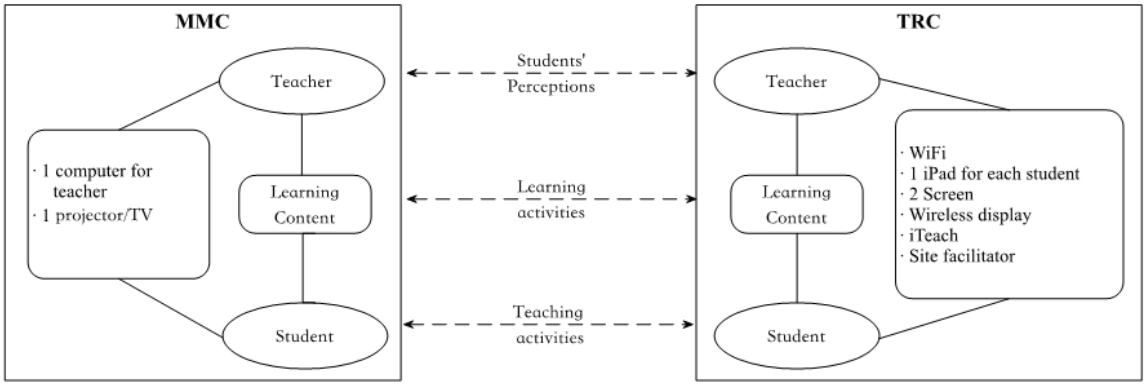

Figure 2. The different configurations of MMC and TRC

Wireless display allowed both teachers and students to project their learning contents to screens. Site facilitators are the experts in integration of technology into education, and helped teachers develop digital pedagogies for integrating the equipped technology into teaching and learning. Classroom pictures showing the different configurations in the MMC and the TRC, are shown in **Figure 3**.

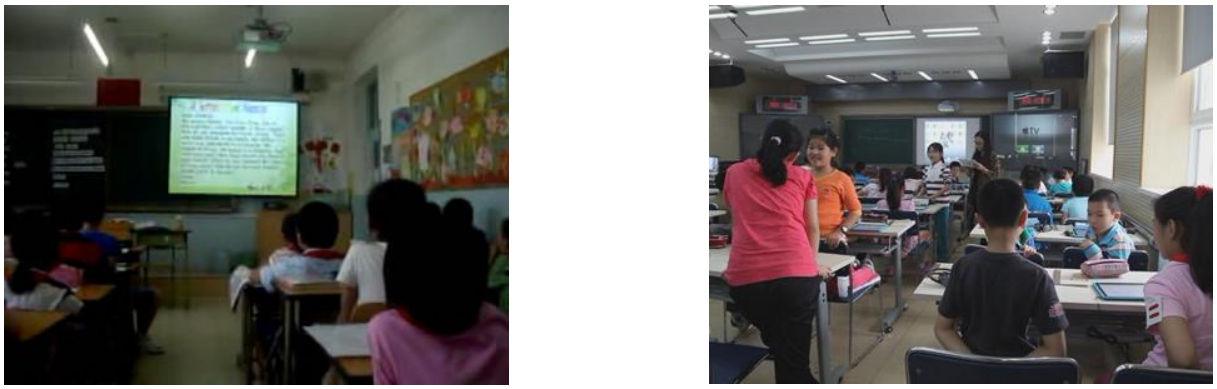

Figure 3. The classroom settings of MMC (Left) and TRC (Right).

Participants

A primary school in Beijing was selected as the experimental school, because of the principal's interest and support to this research, which could enhance and encourage teachers' engagements. Several meetings were held before the experiment, and two English teachers (T1 & T2), with the same level of teaching ability (in terms of documented academic performance of their students), were selected. Each teacher taught the same contents to both an experimental class and a control class at the same time on different weekdays. There were two experimental classes (E1 and E2) operating in a TRC environment, with 32 students in E1 and 38 students in E2; there were two control classes (C1 and C2) operating in a MMC environment, with 35 students in C1 and 38 students in C2, as shown in **Table 1**. In total, 143 students took part in the experiment, with 80 males and 63 females, aged from 10 to 12 years. The experimentation lasted for one semester over a period of 12 weeks.

Table 1. Research design

Groups	English Teachers				Experimental Treatment	Data Collection Tools
	T1	T2	T1	T2		
Experimental Group (n=70)	E1 (n=32)		E2 (n=38)		(1) TRC (2) Co-designed Pedagogy with facilitator and teacher	(1) CEES (2) Tool for behaviour coding in a class
Control Group (n=73)		C1 (n=35)		C2 (n=38)	(1) MMC (2) Tradition Pedagogy	(1) CEES (2) Tool for behaviour coding in a class

Notes: CEES= "classroom environment evaluation scale"

Factors influencing technology integration were expected to be different depending on the technology type, its applications, and the organization involved (Wang, Teo and Russo, 2013). Researchers, teachers, site facilitator, and technology experts had regular meetings before each of the experimental class to help teachers develop co-designed pedagogies for teaching in the TRC. The differences of pedagogies used in MMC and TRC are illustrated in **Figure 4**. All the teaching and learning activities were the same in the MMC and TRC, but more technologies were integrated in the whole teaching and learning process in the TRC. The detailed comparison of instructional design in MMC and TRC could be found in Appendix 2.

Instruments

Classroom Environment Evaluation Scale

Classroom Environment Evaluation Scale (CEES) is a validated scale for evaluating classroom environment designed especially for TRCs equipped with different kinds of technologies (Yang and Huang, 2015) as per the appendix. CEES evaluates classroom environments from both physical and psychosocial aspects. The former includes showing, manageable, accessible, tracking and enhancement. While, the latter includes teacher support, involvement, investigation, task orientation and cooperation.

In the questionnaire, showing stands for the convenient level for presenting and sharing learning or instructional content; Manageable stands for the convenient level for changing classroom layout, dispatching instructional materials, etc.; Accessible stands for the convenient level for accessing and sharing digital learning resources; Tracking stands for the comfortable level of the indicators of the physical environment, like temperature, lighting, electricity, etc.; enhancement stands for the level of facilitation of learning and teaching by technology used in classroom; Involvement stands for the level students feel engaged in classroom learning activity; Teacher support stands for the degree of help taut students can feel from the teacher in class; Investigation stands for the degree to which students conduct inquiry-based learning in class and solve problems using the inquiry method; Task orientation

stands for the degree to which students feel they could finish the learning activities and focus on learning; Cooperation stands for the degree to which students cooperate rather than compete with one another on learning tasks.

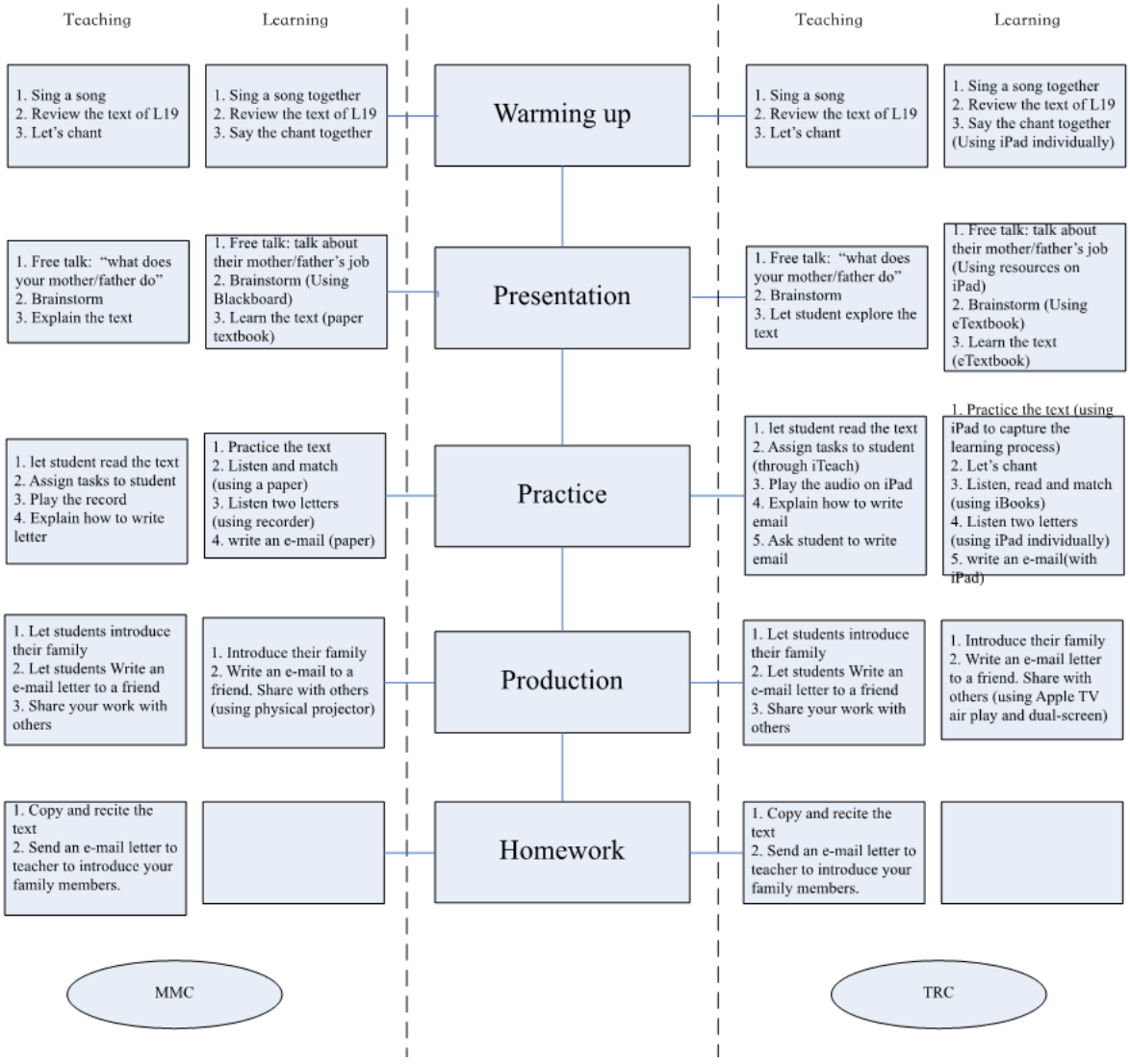

Figure 4. The comparison of the teaching methods in the MMC and TRC

The tool for behaviour coding in a class

Classroom observation is a tool for evaluating teacher effectiveness, assessment of student learning, and assessment of children's behaviour (Massat and Sanders, 2009). International Society for Technology in Education (ISTE) has developed the ISTE Classroom Observation Tool (ICOT) since 2008, which provided observers with a platform for recording observations of technology use in classrooms. In ICOT, both the teachers' teaching activities

and the students' learning activities can be recorded. ICOT includes two student-centered teacher activities (facilitation and moderation) and three teacher-centered activities (lecture, interactive direction, and modeling). ICOT includes six creation and study activities that are primarily student-centered (creating/ delivering presentations, writing, research, information analysis, and running interactive simulations), and three that are primarily teacher directed (tests, drill and practice, and hands-on skill training) (Bielefeldt, 2012). Shi and Cui (1999) proposed that the teaching activities included presentation, dialogue, direction, and other management activities. The Flanders Interactive Analysis System (FIAS) (Flanders, 1970) was the most widely used coding method for teacher and students activities, which includes both teacher-led and pupil-led teacher talk and pupil talk. Based on these tools and considering the features of technology-rich classroom, we proposed a framework for observing teaching and learning activities in TRC, as shown in **Table 2**.

Table 2. The framework for classifying behavior in TRC

Dimensions	**Categories**
Teacher Presentation	Lecturing
	Modelling
	Criticizing
Teacher Guidance	Guiding
	Interactive Direction
	Facilitating/Coaching
Teacher-led Dialogue	Asking Questions
	Answering Questions
	Accepting Ideas
	Praising or Encouraging
	Moderate Discussion
Students' Individual learning	Practicing
	Reading textbook
	Reading after Listening
	Reporting to others
Students' Collaborative learning	Group Discussion
	Group Practicing
	Role-play
	Collecting Learning Resources
	Presenting Group Learning Outcomes

The dimension of teacher presentation is used to record teacher's activity of lecturing, modeling, and Criticizing. Lecturing is teacher's activity of giving facts or opinions about content. Modeling is teacher's activity of demonstrating a procedure students will be expected to do on their own. Criticizing is teacher's activity of asking the pupils not to interrupt with

foolish questions. The dimension of teacher guidance is used to record teacher's activity of guiding, interactive direction, and facilitating/coaching. Guiding is teacher's activity of giving students guidance or hint to help students' solve problem. Interactive direction is teacher's activity of gives directions, commands or orders or initiation with which a pupil/student is expected to comply with. Facilitating/coaching is teacher's activity of tutoring students individually. The dimension of teacher-led dialogue is used to record teacher's activity of asking questions, answering questions, accepting ideas, praising/encouraging, and moderate discussion. Asking question is teacher's activity of asking questions about content or procedures, based on the teacher ideas and expecting an answer from the pupil. Answering question is teacher's activity of answering questions of raised by students. Accepting ideas will be recorded when pupils ideas are accepted by teacher. Praising/encouraging will be recorded when teacher praises or encourages student action or behaviour. Moderate discussion will be recorded when both teachers and students are talking for solving a problem. The dimension of student's individual learning is used to record the learner's individual activity of practicing, reading textbook, reading after listening, and reporting. Practicing is student's activity of doing exercises in class. Reading textbook is student's activity of reading textbook in class. Reading after listening is student's activity of reading after listening in class. Reporting to others is student's activity of presenting and reporting to other students in class. The dimension of student's collaborative learning is used to record learner's collaborative activity of group discussion, group practicing, and role-play, collecting learning resources, and presenting group learning outcomes. Group discussion is students' activity of talking in groups. Group practicing is students' activity of doing practices or tasks in groups. Role-play is students' group activity for role-play. Collecting learning resources is student's group activity of finding learning materials on the Internet in class. Presenting group learning outcome is students' group learning activity of presenting and reporting to others in class.

Live video classroom observation is effective in reducing reactivity and helps avoid subjective judgments, thus providing a solution to compensate for the limitations of traditional classroom observations (Liang, 2015). Therefore, video based classroom observation under the above framework were used to evaluate the differences between TRC and MMC by analyzing the behaviour of students and teachers in each classroom.

The tool for behaviour coding was developed to code learning behaviour and teaching behaviour in the TRC class as shown in **Table 3**. Five dimensions of teacher presentation, teacher guidance, teacher-led dialogue, student's individual learning and student's group learning were included. In this coding system, teacher's behaviour was coded as "TT1", "TT2", etc., and student's behaviour was coded as "SI12", "SI13", etc.

Table 3. The coding scheme for different behavior in a class

Dimensions	Categories	Coding
Teacher Presentation (T)	Lecturing	TT1
	Modelling	TT2
	Criticizing	TT3
Teacher Guidance (G)	Guiding	TG4
	Interactive Direction	TG5
	Facilitating/Coaching	TG6
Teacher-led Dialogue (D)	Asking Questions	TD7
	Answering Questions	TD8
	Accepting Ideas	TD9
	Praising or Encouraging	TD10
	Moderate Discussion	TD11
Students' Individual learning (I)	Practicing	SI12
	Reading textbook	SI13
	Reading after Listening	SI14
	Reporting to others	SI15
Students' Collaborative learning (C)	Group Discussion	SC16
	Group Practicing	SC17
	Role-play	SC18
	Collecting Learning Resources	SC19
	Presenting Group Learning Outcomes	SC20

Data collection and analysis

All the 143 students were asked to rate their agreement with 50 CEES items on a Likert-five-point scale labelled as almost never, seldom, sometimes, often, almost always. The scales were scored so that 1= almost never to 5= almost always. After discarding the invalid questionnaires, due to missing data, 134 valid questionnaires were used in this study. Out of them, 66 were from experimental group and 68 were from control group. The data analyses was conducted with SPSS statistical software (version 20.0), using a statistical significance level of .05 or less for all tests.

24 classroom sessions (12 from E1 and 12 from E2) from the experimental group and 24 classes (12 from C1 and 12 from C2) from the control group were recorded for analysis. The relations of the classes are shown in **Table 4**.

Table 4. Relations between the recorded classes

No.	Subject	Lessons	Categories	Classes	Dates
1	English	Unit 2 Lesson 1 Look at his yellow hair.	Control group	C1	April 9
2	English	Unit 2 Lesson 1 Look at his yellow hair.	Experimental group	E1	April 10
3	English	Unit 2 Lesson 2 He looks friendly.	Control group	C2	April 11
4	English	Unit 2 Lesson 2 He looks friendly.	Experimental group	E2	April 12

Two research assistants coded the teaching behaviour and learning behaviour independently by playing-back the 48 recording videos, of which each lasted about 40 minutes. The two research assistants were trained on how to use the tools for coding before their work. In the process of coding, if the coding from the two assistants conflicted, the researcher would help them to achieve agreement. The format for coding is shown in **Table 5**.

Table 5. Formats for coding teaching and learning behaviour

No.	Time begins	Time lasts (s)	Coding of teaching behavior	Coding of learning behavior	Notes
1	0:00:00	55	TT2		Teacher uses projector and iPads to play video
2	0:00:55	30	TD7		Teacher asks questions
3	0:01:25	43	TD11		Teacher discusses with students on their problems
4	0:02:08	300		SC19	Students collect learning resources for group task
.....					

In the end, the total time for each coding in each video were computed. For each behaviour in the class, the total time which was the sum of lasting time for that behaviour, were used in the analysis in SPSS, as shown in **Table 6**. Please notice that the time format in the table has been changed to decimals for analysis.

RESULTS

Reliability and validity of CEES questionnaire

Firstly, the reliability of the instruments was checked. Cronbach's coefficient alpha value for the whole CEES was 0.97, and Indices for each dimension ranged from .75 to .92. Then, factor analysis was undertaken to explore the structural validity of CEES questionnaire. Principal components factor analysis, followed by Oblimin with Kaiser Normalization rotation, was performed to confirm the structure of CEES, using individual students' mean score as the unit of analysis. The physical factors of S, M, A, T, E and the the psychosocial factors of IN, TS, IV, TO and CO was performed separately. For any item, its factor loading is

at least 0.40 within its own scale and less than 0.30 with each of the other scales. The results of the final factor loadings were presented in **Table 7**. Thus, we confirmed the reliability and validity of the CEES questionnaire.

Table 6. The final activity data for analysis in SPSS

Dimensions	Categories	Class1(minutes)	...	Class48(minutes)
Teacher Presentation (T)		12.83	...	6.45
Teacher Guidance (G)		1.62	...	2.12
Teacher-led Dialogue (D)		12.16	...	12.59
Students' Individual learning (I)	Practicing	3.01	...	2.11
	Reading textbook	1.70	...	3.12
	Reading after Listening	0.00	...	1.00
	Reporting to others	1.50	...	1.98
Students' Collaborative learning (C)	Group Discussion	3.13	...	2.11
	Group Practicing	3.01	...	3.11
	Role-play	1.70	...	3.12
	Collecting Learning Resources	0.00	...	0.00
	Presenting Group Learning OuMMComes	0.00	...	1.98

Table 7. Factor loadings for each subscale

	S	M	A	T	E	IN	TS	IV	TO	CO
1	.883	-.807	.911	.743	-.757	.800	.904	.855	.792	.717
2	.821	*-.732*	*.825*	*.735*	-.725	*.743*	.819	.846	.788	.712
3	.732	*-.686*	*.740*	*.692*	-.616	*.562*	.804	.751	.763	.689
4	.591	*-.640*	*.723*	*.671*	-.605	*.468*	.790	.744	.735	.598
5	.456	*-.546*	*.520*	*.568*	-.538	*.448*	.680	.648	.730	.541

Student's perceptions of MMC and TRC

An independent-samples t-test was conducted to investigate if there were significant differences in each scales of CEES between TRC and MMC. The independent samples t-test was significant for Showing, Accessible, Tracking, Enhancement, Involvement, Investigation, Task Orientation and Cooperation in $p<0.01$, and Teacher Support in $p<0.05$; while no significance existed for Manageable between TRC and MMC, as shown in **Table 8**.

The mean scores in MMC for all the scales except for M, T and TO were under 4.00, which indicates that students in the MMC perceived the phenomenons asked about between sometimes and often. In other words, they generally did not perceive their English classroom environments favorably. The mean score for Accessible was only 3.35 in MMC, which indicates that students had little convenience for accessing and sharing digital learning resources in MMC; while students perceive significant more convenience in TRC with the equipment of iPad for each student and free WiFi.

Table 8. Comparison of students' perceptions of MMC and TRC

Scale	MMC (n=67)	TRC (n=66)	Independent-samples t-test		
	Mean (S.D.)	Mean (S.D.)	t	df	Sig. (two-tailed)
Showing (S)	4.18(0.728)	4.56(0.733)	-3.020	132.0	0.003**
Manageable (M)	4.21（0.782）	4.447（0.788）	-1.719	127.0	0.088
Accessible (A)	3.35(1.275)	4.26(1.000)	-4.568	131.0	0.000**
Tracking (T)	4.13(0.797)	4.46(0.814)	-2.337	132.0	0.000**
Enhancement (E)	3.86(1.102)	4.56(.717)	-4.317	132.0	0.000**
Involvement (IN)	3.55(1.102)	4.18(0.939)	-3.475	127.0	0.001**
Teacher Support (TS)	3.81(1.100)	4.28(1.055)	-2.572	132.0	0.011*
Investigation (IV)	3.66(1.133)	4.33(.887)	-3.771	132.0	0.000**
Task Orientation (TO)	4.19(.941)	4.64(.557)	-3.299	132.0	0.001**
Cooperation (CO)	3.73(1.197)	4.44(.822)	-4.024	132.0	0.000**

The mean scores in TRC for all the scales were above 4.00, which indicates that students perceived their English classroom environments favorable in TRC. Moreover, the mean scores of S, TO and TE in TRC were above 4.5, which indicates that students perceived very good experience in TRC for learning content presentation, task orientation and enhancement. Students also perceive significantly more investigation, collaboration, and teacher support in TRC than in MMC, indicating that student's' learning behaviour were different in TRC and MMC.

Learning behaviour in MMC and TRC

In order to know what happened in the classroom, we analyzed the learning behaviour and teaching behaviour in both the MMC and TRC. Learning behaviour in classroom included individual learning and collaborative learning. The former included practicing, reading

textbook, reading after listening, sharing learning outcomes, and the latter included group discussion, group practicing, role-play, collecting learning resources and sharing group learning outcomes. The results of independent-samples t-test was shown in **Table 9**, revealing the significant differences in both individual learning behaviour and collaborative learning behaviour between TRC and MMC. Students in TRC had more time engaged in both individual learning and collaborative learning than students in MMC.

Table 9. Comparison of students' learning behaviour in MMC and TRC

Dimensions	**MMC（n=24）**	**TRC（n=24）**	**Independent-samples t-test**	
	Mean (S.D.)	Mean (S.D.)	t	Sig.
Students' Individual Learning	7.167 (1.411)	8.893 (.871)	5.098	.000**
Students' Collaborative Learning	7.158 (1.961)	11.070 (1.613)	7.481	.000**

***p<0.01*

As a follow up, two separate independent t-tests were conducted to determine which of the behaviour were significantly contributing to the differences in student's individual learning behaviour and collaborative learning behaviour. The results revealed that participants in TRC had more time to do "Reading after Listening" and "Sharing Learning Outcomes" than participants in MMC, as shown in **Table 10**, but there were no significant differences in "Practicing" and "Reading textbook" in TRC and MMC.

Table 10. Comparison of students' individual learning behaviour in MMC and TRC

Dimensions	**Categories**	**MMC （n=24）**	**TRC（n=24）**	**Independent-samples t-test**	
		Mean (S.D.)	Mean (S.D.)	t	Sig.
Students' Individual Learning Behaviour	Practicing	3.320(1.504)	2.690(1.326)	-1.539	.131
	Reading textbook	2.562(1.359)	2.634(1.556)	.225	.823
	Reading after Listening	.000(.000)	1.301(1.317)	4.893	.000**
	Sharing Learning Outcomes	1.285(0.955)	2.268(.762)	3.940	.000**

***p<0.01*

With regard to collaborative learning behaviour, the results revealed that participants in TRC had more time to conduct "Group Discussion", "Collecting Learning Resources" and "Sharing Group Learning Outcomes", as shown in **Table 11,** but there were no significant differences in "Group Practicing" and "Role-play" in TRC and MMC.

Table 11. Comparison of students' collaborative learning behaviour in MMC and TRC

Dimensions	Categories	MMC（n=24）	TRC（n=24）	Independent-samples t-test	
		Mean (S.D.)	Mean (S.D.)	t	Sig.
Students' Collaborative Learning Behaviour	Group Discussion	1.314(1.088)	2.414(1.422)	2.969	.005**
	Group Practicing	2.850(1.450)	3.003(1.249)	.392	.697
	Role-play	1.972(1.489)	1.921(1.556)	-.116	.908
	Collecting Learning Resources	.000(.000)	1.359(2.267)	2.937	.007**
	Sharing Group Learning Outcomes	1.038(0.922)	2.237(.692)	5.671	.000**

**p<0.01

Teaching behaviour in MMC and TRC

Independent t-test showed that teacher's "Presentation" and "Guidance" behaviour had significant differences in TRC and MMC in the level of p<0.01, and the "Dialogue" in the level of p<0.05, as shown in **Table12**. In TRC, teacher used less time to conduct "Presentation" and "Dialogue", but more time to "Guidance". Totally, teacher in TRC saved an average of 4 minutes for conducting the same activities in a 40 minutes' class, compared with teacher in MMC.

Table 12. Comparison of teacher's teaching behaviour in MMC and TRC

Dimensions	MMC（n=24）	TRC（n=24）	Independent-samples t-test	
	Mean (S.D.)	Mean (S.D.)	t	Sig.
Presentation	10.468(2.038)	6.070(.744)	-9.929	.000**
Guidance	1.566(.518)	2.750(.631)	7.099	.000**
Dialogue	13.170(1.299)	12.416(.757)	-2.455	.018*
Total	25.204(1.974)	21.235(1.057)	-8.682	.000**

*p<0.05 **p<0.01

DISCUSSION

The findings from the survey indicates that participants in TRC experienced more significant convenience in presenting learning materials, accessing to technology/resources and more technology facilitated learning enhancement than participants in MMC. In TRC, WiFi, iPads, iTeach, and wireless display screen were equipped for all students, while in MMC only computers and a projector was equipped for teachers. The results showed that technologies for students in classroom, such as digital devices, Internet, and screens, were vital for students' perceptions of classroom physical environments. This confirmed the claim that today's students expect technology as part of the learning environment (Tapscott, 2008), and

students' learning preferences should be considered in the design and evaluation of learning environment (Brown, 2005). Students' perceptions to psychosocial classroom environments revealed that they experienced more teacher support, involvement, investigation, cooperation and task orientation in TRC than in MMC. Previous research had shown that students' perceptions of the classroom environment are related significantly and positively to their learning outcomes (Fraser, 1998; Goh and Khine, 2002; Dorman, 2009; Brooks, 2011). We predict that students in TRC will have better outcomes than students in MMC, which should be confirmed in the next research.

WiFi and digital device for each student was essential to improve students' perception of classroom environments, as the digital native preferred to use technology to learn and solve problems (Teo, 2013; Yang, Huang, and Kinshuk, 2016); wireless display and dual screen for students were vital for showing, sharing the learning outcomes and cooperation, as the digital native relied on graphics for communication (Prensky, 2001; Teo, 2013). There were no significant differences of students' perception with manageable in TRC and MMC, the reason of which was probably that the classroom layout was still "rows of seats and tables facing forward" in TRC (Fig. 2). Therefore, SMATE model could serve as a framework for equipping classroom according to digital native's learning preference.

Students in TRC had 3.91 more minutes for collaborative learning and 1.73 more minutes for individual learning than students in MMC, which confirmed the survey results that students had significantly more positive perceptions of involvement, investigation, task orientation and cooperation in TRC than in MMC. Students in TRC had more time for group discussion, collecting learning resources, sharing learning outcomes, and reading after listening than students in MMC. Both the presentation time and dialogue time were significantly shorter in TRC than in MMC, but the guidance time were significantly longer in TRC than in MMC. Those differences of students' learning behaviour in MMC and TRC showed that students had more time for individual learning and collaborative learning in TRC, which indicated a more student-centered learning model in TRC. At the same time, the survey results showed that students had a more positive learning experience in TRC than in MMC. The results of this study showed that change of classroom environment could change teaching behaviour and learning behaviour, which also confirmed our assumption that designing and using TRC is one of the methods for changing the classroom from teacher-centered learning to more student-centered learning.

However, we must notice that the behaviour change in classroom is not just because of the technology equipment according to SMATE model, but these behaviour changes in classroom is a combination of the both the equipment and pedagogy. For enhancement, the site facilitator plays a critical role to help teachers develop adaptive pedagogies according to the new classroom environment. Pedagogy adopted by teachers plays another important role in students' perception to the classroom environment. Physical classroom environments equipped with technologies interacts with pedagogy adopted by teachers. Different pedagogy asks for different learning space, and vice versa (Radcliffe, 2009). In this research, teachers in

TRC developed pedagogies suitable for the new equipped technology-rich classroom with researchers, site facilitators, and technology experts. Co-design method was the key for the success of this technology-rich classroom project. The co-design process relied on teachers' ongoing involvement with the design of educational innovations, which typically employed technology as a critical support for practice (Penuel, Roschelle, and Shechtman, 2007). Therefore, we draw a model to illustrate the different "forces" to improve learner's perceptions and teaching and learning behaviour in classroom, as shown in **Figure 5**. In this study, technology was equipped in classroom according to the SMATE model; the co-design of site facilitator, teacher and researcher was used to produce enhanced pedagogy; both the technology equipment and the enhanced pedagogy contributed to the change of teaching and learning behaviour in classroom, and neither should be missed.

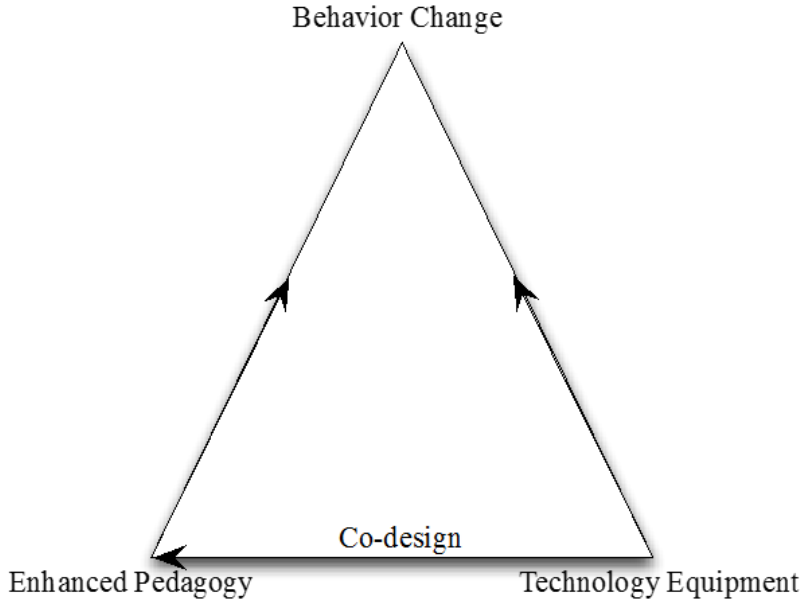

Figure 5. Classroom change model

These differences of learning behaviour and teaching behaviour in TRC and MMC also confirmed the reliability of the CEES. As students had more time for group discussion and group practicing in TRC than MMC, the score of their perceptions on cooperation in TRC was higher than score in MMC. Students used more time for collecting learning resources in TRC than in MMC, and the score of perceptions on investigation in TRC was higher than the score in MMC. Teachers used more time for guidance in TRC than MMC, and the score of students' perception on teacher support was higher than the score in MMC. Both the research method of questionnaire and classroom observation are important for classroom environment research, and the two methods could be used together to validate each other to reach a more reliable conclusion.

CONCLUSION

The study found that student's perceptions of classroom learning environment and their learning behavior were different in TRC than those in MMC. Students had more time for both individual learning and collaborative learning in TRC, and teachers used more time for guidance students and less time for presentation in TRC. Student's perceptions on learning environments in TRC were significantly better than their perceptions in MMC. This study showed that change of classroom environment could change teaching behaviour and learning behaviour, which confirmed also our assumption that designing and using TRC is one method for changing the classroom from teacher-centered learning to more student-centered learning.

This research also revealed that the adapted SMATE model could be used as a framework for designing technology-rich classroom environment by considering digital learner's learning preference and teacher's pedagogical issues. The configuration of Internet access and digital devices for each student in classroom were vital for improving learning experience as these were the basis for conducting inquiry and collaborative learning by using digital resources. Wireless display and shared screens for students in classroom were crucial for sharing learning outcomes and promoting interaction. Although the design and use of TRC play an important role for improving learning experience, it is just one of the factors influencing learner's perceptions on learning environments and learning behaviour. Pedagogy fitness for the TRC is another critical factor. Teachers should develop different pedagogies in newly developed TRCs. Co-design methods served as an important role to develop suitable pedagogies for specific TRC in technology integration programs.

Owning to the research limitation, not all of the five dimensions of SMATE model were taken into consideration when designing TRC in this study. In the future study, manageable and tracking should also be included for designing TRC. This research was conducted at one primary school only, which can be considered either a starting point for further research, or as a toolkit for other researchers to utilize. We plan to use all the five dimensions of SMATE model to build a TRC for STEM education, and investigate how TRC will be used by teachers to train student's 21st century learning skills. Additionally, teacher's professional development in TRC also presents an interesting research issue that warrants further research.

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Appendix1: Classroom Environment Evaluation Scale (CEES)

Please rate the following statements with 1=Almost Never, 2=Seldom, 3=Sometimes, 4=Often, 5=Almost Always.

In class

1. I can hear teacher clearly

2. I can hear other students clearly

3. I can see projected visuals clearly from my seat.

4. I can share my learning outcomes with others

5. I understand teaching content better with multi-screen display

In class

6. The layout in classroom is suitable for my ways of learning

7. I have adequate workspace for the placement of textbooks, tablet PCs and other resources

8. Adequate space exists for easy movement among workstations, resources and exits

9. The podium, blackboard and projector are at the right place for teaching and learning

10. Layout is flexible to change according the different pedagogical needs

In class

11. I can get on Internet

12. I can get digital learning resources

13. I can share digital resources with peers

14. Teacher can get on Internet

15. Teacher can use abundant digital learning resources

In class

16. Light in classroom is enough for reading books or digital books

17. Temperature in classroom is suitable for concentrating on learning

18. No unnecessary noises exist in classroom

19. I don't feel sleepy in classroom because of fresh air in classroom

20. I can find that computer sockets in classroom when I need to use them

In class, technology enable

21. The course content is more abundant.

22. It is easy for students to understand scientific principles.

23. The teacher presents more real-world phenomena.

24. Technology enables students to explain concepts in alternative ways.

55. Time to go through the course content is shorter.

In class,

26. The teacher takes a personal interest in me.

27. The teacher considers my feelings

28. The teacher helps me when I have trouble with the work.

39. The teacher talks with me

30. The teacher's questions help me to understand

In class,

31. I give my opinions during class discussions.

32. The teacher asks me questions.

33. My ideas and suggestions are used during classroom discussions.

34. I ask the teacher questions

35. I explain my ideas to other students.

In class,

36. I carry out investigations to test my ideas

37. I am asked to think about the evidence for statements.

38. I carry out investigations to answer questions coming from discussions.

39. I carry out investigations to answer questions that puzzle me.

40. I carry out investigations to answer the teacher's questions.

In class,

41. I do as much as I set out to do.

42. I know the goals for this class.

43. I know what I am trying to accomplish in this class.

44. I pay attention during this class.

45. I try to understand the work in this class.

In class,

46. I cooperate with other students when doing assignment work.

47. I share my resources with other students when doing assignments

48. When I work in groups in this class, there is teamwork.

49. I learn from other students in this class

50. Students work with me to achieve class goals.

Appendix2: Comparison of Instructional design in MMC and TRC

Instructional process	MMC			TRC		
	Teaching activity	Learning activity	Use of Media	Teaching activity	Learning activity	Use of Media
Warming-up 3'	1. Sing a song: Be what you want to be. 2. Review the text of L19 3. Chant	Sing the song together. Review the text. Say the chant together.	Video PPT	1. Sing a song: Be what you want to be. 2. Review the text of L19 3. Chant	Sing the song together. Review the text. Say the chant together (using iPad individually).	Video PPT e-textbook in iPad
Presentation 15'	1. Free talk What does your father / mother do? (providing pictures of all kinds of work) 2. Topic: Today we are going to talk about the jobs and working places. I also want to know about you and your family. 3. Brainstorm 4. Text (1) Topic picture ① Introduce Gao Wei. ②What do you want to know about him? (2) Paragraph One ① Enjoy the video	Talk about their father or mother's job. Say the jobs and working places together. Ask the questions about Gao Wei. Enjoy the video (through teacher's PPT) Answer the questions Enjoy the video one more time.	Pictures PPT Video	1. Free talk What does your father / mother do? (providing pictures of all kinds of work) 2. Topic: Today we are going to talk about the jobs and working places. I also want to know about you and your family. 3. Brainstorm 4. Text (1) Topic picture ① Introduce Gao Wei. ②What do you want to know about him? (2) Paragraph One ① Enjoy the video ② Answer the questions	Talk about their father or mother's job. Say the jobs and working places together. Ask the questions about Gao Wei. Enjoy the video (with iPad for each student) Answer the questions Enjoy the video one more time.	Pictures PPT Video PPT e-textbook in iPad

	② Answer the questions ③ Enjoy one more time Q: What are the questions? ④ Answer the questions Where do they work? (3) Paragraph Two ① Listen and choose. ② Check answer ③ Learn "bank" Read after me. Find someone to read it. See some pictures about bank. My father works in a bank. My mother works in a school.	Answer the questions Listen and choose (teacher play the recording). Check answer. Read Bank. See some pictures about bank.	Audio	③ Enjoy one more time Q: What are the questions? ④ Answer the questions Where do they work? (3) Paragraph Two ① Listen and choose. ② Check answer ③ Learn "bank" Read after me. Find someone to read it. See some pictures about bank. My father works in a bank. My mother works in a school.	Answer the questions Listen and choose. Check answer (e-textbook). Read Bank. See some pictures about bank.	doing exercises in iPad
Practice 15′	1. Practice the text (1) Listen and repeat (2) Practice in pairs. 2. Chant 3.explain how to write letter (1) How many parts does an e-mail have? (subject, to, text) (2) The e-mail's format. Now let's see these three parts and let's see how to write an e-mail letter.	Listen and repeat together. Practice in pairs. Chant. Listen two letters (using recorder). Try to understand how to write an e-mail letter. Write email (paper)	PPT Audio Paper	1. Practice the text (1) Listen and repeat (2) Practice in pairs. (Recording with iPad) 2. Chant 3.explain how to write letter (1) How many parts does an e-mail have? (subject, to, text) (2) The e-mail's format. Now let's see these three parts and let's see how to write an e-mail letter.	Listen and repeat together. Practice in pairs. Chant. Listen two letters (using e-textbook). Try to understand how to write an e-mail letter. Write email (with iPad)	PPT Recording iPad
Product 7′	1. Talk about the teacher's family. Wow! It's me. Now I want to introduce my family to you. My name's Nancia. I'm from China. I'm 31. I'm a primary school teacher. I teach English. There are three	Listen to teacher carefully. Answer the questions.	PPT PPT	1. Talk about the teacher's family. Wow! It's me. Now I want to introduce my family to you. My name's Nancia. I'm from China. I'm 31. I'm a primary school teacher. I teach English. There are three	Listen to me carefully. Answer questions.	PPT

	people in my family. My mother is a secretary. She works in a company. My father is driver. He works in a company, too. How about you? 2. Practice in pairs. 3. Show my e-mail letter. So I write down an e-mail letter to you. Because I really want to know more about you and your family. 4. Our father and mother work very hard. They love you very much. We should love our father and mother. I wish you have a happy family.	Practice in pairs Show the email to others (physical projector)	Paper Letter	people in my family. My mother is a secretary. She works in a company. My father is driver. He works in a company, too. How about you? 2. Practice in pairs. 3. Show my e-mail letter. So I write down an e-mail letter to you. Because I really want to know more about you and your family. 4. Our father and mother work very hard. They love you very much. We should love our father and mother. I wish you have a happy family.	Practice in pairs Show the email to others (using APPLE TV air play and dual-screen)	Air play by APPLE TV Screen for student's projection PPT Send emails by using iPad Letter
Homework 1′	1. Copy and recite the text of Lesson 21. 2. Send the e-mail letter to your friend to introduce you and your family.			1. Copy and recite the text of Lesson 21. 2. Send an e-mail letter to your friend to introduce you and your family.		
Design of writing on the blackboard	Unit 4 What does your mother do? Lesson21 What do your parents do? My father works in a bank. My mother works in a school.			Unit 4 What does your mother do? Lesson21 What do your parents do? My father works in a bank. My mother works in a school.		