Preparing pre-service teachers for instructional innovation with ICT via co-design practice

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Information and communications technology (ICT) is rapidly changing how we teach and how we learn. ICT can not only act as a teaching and learning aid but also reshape the delivery of instruction and bring about changes in education. Research has largely examined the effects of teacher education programs on their knowledge, attitudes, and beliefs of technology integration and relatively little attention has been paid to their ability to use ICT to innovate instruction. This study examined how pre-teachers engaged in co-design via Google Slides, and how their behavioural characteristics influenced their improvement of instructional innovation with ICT of lesson design. The results of correlation and step regression analyses and lag sequential analysis showed that behaviours of engagement into individual ideation and within-group ideation in co-design activities positively related to the pre-service teachers' innovations of lesson designs (i.e., usefulness and originality). The clarification type and positive affection type of peer feedback negatively related and predicted their innovations, and the worst-performed group tended to directly copy information from peer feedback. The implications of how pre-service teachers engaging in co-design activities affect their instructional innovations with ICT are discussed.

Implications for practice or policy

- Co-design activities are helpful for instructional innovation for pre-service teachers.
- Pre-service teachers are encouraged to engage in individual ideation, group ideation, and peer feedback during co-design activities.

Keywords: pre-service teachers, instructional innovation, information and communications technology (ICT), co-design, peer feedback

Introduction

Information and communications technology (ICT) is rapidly changing how we teach and how we learn. These changes affect instruction at various levels by, for instance, creating new instructional structure (beyond school time and physical space structure), devising novel instructional solutions or through expanding the school's knowledge-resources space into the Internet (Wilson et al., 2020; Wong et al., 2008). Therefore, ICT can not only act as a teaching and learning aid but also reshape the delivery of instruction and bring about changes in education.

Teachers need to move beyond using ICT to reinforce old pedagogies and towards innovating instruction with it. As an ICT does not contain a pedagogical philosophy or content basis, it does not occur to teachers to use ICT to innovate their instruction. Consequently, teachers' education programmes for technology integration have been drawn up all over the world (e.g., the United States of America, Japan and Finland). Research has largely examined the effects of these programmes on their knowledge, attitudes and beliefs of technology integration, on the basis of the technological pedagogical and content knowledge framework, which proposes that effective use of technology requires complex forms of teacher knowledge that integrate content, pedagogy and technology (Birisci & Kul, 2019; Farjon et al., 2019; Koehler et al., 2007; Wilson et al., 2020). However, little attention has been paid to teachers' ability to use ICT to innovate instruction.

Instruction includes complex interrelationships among a multifaceted as well as a disparate set of factors and variables, such as pedagogies, pragmatic decisions and educational resources available (e.g., physical, economic, temporal) and the people involved (e.g., students, teachers and managers). Instructional innovations may relate to any of these variables and interactions among them. Generally, ICT changes the presentation of curriculum content, the instructional process and the ways of teacher-student interaction. Therefore, it is widely believed that ICT innovates schooling (Mioduser et al., 2003; Wong et al., 2008).

Several frameworks have been developed by researchers and educational practitioners to characterise the ways ICT may support and promote instructional innovation (Bransford et al., 2000; Kozma & Anderson, 2002; Means et al., 1993). For example, Bransford et al. suggested that instructional innovation with ICT focuses on whether ICT is supporting knowledge construction, and whether it is being used in ways that enable new learning opportunities that would not be possible without it. Furthermore, researchers have elaborated on how ICT innovates instruction (Kozma & Anderson, 2002; Means et al., 1993). For example, Means et al. suggested that technology may support the reformation of instructional approaches in several dimensions, for example, the curriculum, time configuration, teacher and student practices and roles, grouping and collaboration. Taken together, instructional innovation can be defined in operational terms as the wide range of activities and means (e.g., curricular decisions, learning materials, learning configurations, lesson plans, tools and resources) (Mioduser et al., 2003).

In spite of the common view of the power of ICT, few programmes have focused on promoting pre-service teachers' abilities to use ICT to innovate instruction. For instance, Abbitt (2011) ran four different courses for technology integration, which focused on pre-service teachers' application of specific software and educational technology. Indeed, several empirical studies have shown that ICT innovates schooling in unique ways, such as success in devising innovative classroom instructions and lesson design (Mioduser et al., 2003; Shear et al., 2014). Given the potential for teacher education programmes to address beliefs, attitudes and knowledge, they might promote teachers' ability to use ICT to innovate instruction. In the present study, we analysed how pre-service teachers' ability to use ICT to innovate instruction was improved via online collaborative lesson design practice.

Teacher education programmes address technology integration in multiple ways, including stand-alone courses, course series, mini workshops and co-design practices, offer opportunities to understand concepts in deeper, often different, and more meaningful ways (Lee & Lee, 2014; Yough et al., 2019). Many researchers have emphasised the importance of content-specific practice of using technology in teacher education programmes (Janssen & Lazonder, 2016; Koehler & Mishra, 2005; Saban & Çoklar, 2013). In line with this perspective, Koehler and Mishra proposed a constructivist approach called learning technology by design, where teachers learn effective technology integration as they participate in authentic and situated pedagogical tasks. The design-based approach assumes that teachers take a more active role as instructional designers who value technology as an effective instructional tool, rather than staying as a passive technology recipient (Koehler et al., 2004).

Moreover, W. Chen et al. (2021) and Wen et al. (2012) considered that by engaging a collaborative lesson design approach to lesson design, more opportunities would be created for sharing wider perspectives in the use of ICT into the instructional design that enabled knowledge improvement at individual, group and class level.

This collaborative design process relies on teachers' ongoing involvement with the design of educational innovations, which typically involve technology as critical support for improving teaching practice. Learning scientists claim that during the co-design process, teachers pay close attention to their everyday work practices and their classroom contexts; furthermore, teachers are active participants in co-design and are viewed as professional contributors to reforms (Peters & Slotta, 2009). Many studies have shown that teachers can produce more usable innovations in a wide range of curriculum materials (e.g., science, mathematics) and expand their ability in the process of improving teaching and learning via co-design practices (Penuel et al., 2007; Severance et al., 2016). Therefore, co-design requires attention to the usability and originality of designs in particular learning contexts.

Co-design cannot guarantee that teachers commit to and engage in actions that reflect personally meaningful goals and that result in instructional innovation with ICT (i.e., new forms of activity in their classrooms) (Severance et al., 2016). Studies on collaboration have shown that participants can produce more useful and original ideas by building on others' ideas, as well as reviewing and commenting on the ideas (G. Chen et al., 2020; Pi et al., 2019). However, we know little about the behavioural characteristics of the co-design process contributing to pre-service teachers' improvement in their ability of instructional innovation with ICT.

The present study aimed to examine how pre-teachers engaged in co-design via Google Slides and how their behavioural characteristics influenced their improvement of instructional innovation with ICT of lesson design. Two research questions were crafted as follows:

(1) What is the relationship between behaviours and the innovation of lesson design in the co-design activities, participants' behaviours in the co-design activities?
(2) How do the pre-service teachers' behaviours affect their innovation of lesson designs in co-design activities?

Method

Participants

A total of 60 pre-service Chinese language teachers (three of whom were male) studying at the National Institute of Education, Nanyang Technological University, Singapore, participated in the study. Of the 60 participants, 21.66% were 20–25 years of age, 43.33% were 26–30 years old and the rest were above 30 years old. They all took a course titled The use of ICT in Character and Citizenship Education and Chinese Language Learning. The lecturer had rich experience in teacher professional development and can use technology effectively for teaching.

The research was approved by the Ethics Committee of the National Institute of Education, at Nanyang Technological University (IRB ref: IRB-2019-04-014). The participants were volunteers who provided written informed consent. They were advised that they had the right to withdraw from the study at any time without penalty. Confidentiality was ensured by using numbers instead of names in the research database. Data were only used for research purposes. Therefore, the research did not involve any unusual hazards inherent. There was no conflict of interest, as we conducted the study only as part of our research programme.

Co-design activity

The study was carried out in face-to-face classrooms. Participants were allocated by the university to three classes with 19, 20 and 21 students in each class. They then chose to join a group of 3 or 4 members. All groups carried out a co-design activity via Google Slideson technology-enhanced lesson for Chinese language learning for one learning text from the national curriculum.

During each co-design activity, group members were required to generate individual ideas and complete a co-design together. The group leader coordinated group actions and checked other members' progress of the given task. After the co-design, inter-group critique took place, in which everyone presented their individual comments. Finally, each group finished intra-group refinement based on the peer comments.

Coding schemes

Evaluation of lesson design innovation
The innovation of lesson designs was evaluated following the standards of previous studies on innovation and creativity in terms of usefulness and originality (Li et al., 2015; Pi et al., 2019). Usefulness refers to whether the lesson design can be implemented in real instructional activities. Originality refers to whether the lesson design reforms traditional instruction. For each lesson design, originality and usefulness were each rated on a 7-point scale by two trained coders. The coders, who were blind to the study goal, showed high inter-rater agreement on usefulness and originality dimensions (respectively, .72 and .86; $p < .001$). The coders scored lesson designs on five dimensions: (a) curricular decisions, (b) learning materials; (c) learning configurations; (d) lesson plans; (e) ICT tools and educational resources (Mioduser et al., 2003).

Behaviours during co-design
In order to analyse group members' behavioural pattern during collaborative lesson design activity, a coding scheme was developed by adapting existing coding schemes (W. Chen et al., 2019; Hou & Wu, 2011; Lu & Law, 2012; Tan & Chen, 2022; van de Pol et al., 2019; Wang et al., 2020): The coding scheme consists of a total of 13 coding items, which can be classified into five dimensions (1) coordination (C), (2) group lesson design (G1), (3) individual lesson design (I1), (4) peer feedback (PF), and (5) uptake (U) (shown in Table 1).

The analysis unit for the participants' behaviour was based on one independent behaviour executed by one participant when they engaged in the collaborative lesson design. Each group's lesson design artefact in Google Slides and their behavioural traces were downloaded and analysed. In the Google Slides, participants could post separately and simultaneously at a group level or class level, and they could also monitor others' work. All their behaviours were recorded by Google Slides. Every behaviour was coded based on its chronological order. The co-design among the 60 participants produced 1051 behaviours, which were analysed to find behavioural patterns. Each participant produced 18 behaviours on average. One third of posts were coded by the two trained coders, and they showed satisfactory inter-rater reliability (Kappa = .94, $p < .01$; Landis & Koch, 1977).

Table 1
Coding scheme for the behaviours during co-design

Dimension	Code	Behaviour	Description
Coordination	C1	Lead task coordination or guide group actions	Instructions or actions that guide group members to perform certain actions, e.g., assign tasks and discuss strategies.
	C2	Check or observe the progress on the learning task	Check other group members' work progress with the given task or report their progress to others.
Group lesson design	G1	Add information to co-design	Provide information on the group artefacts.
Individual lesson design	I1	Individual lesson design	Write the lesson design individually.
Peer feedback	PF1	Peer feedback: assess an idea	Judge the quality of an idea.
	PF2	Peer feedback: clarification	Ask questions to clarify an idea.
	PF3	Peer feedback: suggestion	Provide suggestions to an idea.
	PF4	Peer feedback: positive affection	Express positivity (e.g., like/good) to an idea.
	PF5	Peer feedback: negative affection	Express negativity (e.g., bad idea) to an idea.
Uptake	U1	Uptake: copy	Repeating, mentioning or copying the support feedback (e.g., an explanation) to the lesson design.
	U2	Uptake: apply	Use or apply the feedback given to revise the lesson design.
	U3	Uptake: copy without revision	Repeating, mentioning or copying the feedback by responding to the comments without actual revision to the lesson design.
	U4	Uptake: apply without revision	Applying the feedback through replying to the feedback comments without actual revision to the lesson design.

Data collection and analysis

We created a detailed model of actions and sequences across time by extracting the version history from the Google Slides during the entire online co-design process. Based on analytical frameworks for online discussion (W. Chen et al., 2019; Wang et al., 2020), we coded pre-service teachers' behaviours into the behavioural codes as indicated in Table 1. Based on the coded data, we conducted lag sequential analysis (LSA) to analyse the behavioural pattern of the participants as they engaged in the online co-design activity.

LSA

LSA is used mainly to test the probability that one behaviour occurs after another behaviour and whether it is statistically significant (Bakeman & Gottman, 1997). In order to explore the behaviour patterns in online collaborative learning, we used GSEQ version 5.1 for LSA. Firstly, we imported the coded collaborative behaviour sequences into GSEQ and saved them as an independent document. Then, we used the function of calculating table statistics in GSEQ to summarise the frequency of behavioural types and the adjusted residual results of transitions (i.e., Z score; Z score > 1.96 indicates the behaviour path has significance). Finally, we illustrated the behaviour transition diagrams based on all the sequences that were statistically significant.

Results

The results consisted of two parts. First, in order to understand the relationship between participants' behavioural patterns and their lesson design innovation during the co-design activities, correlation and regression analysis were conducted. Second, to understand how the participants' behavioural patterns during the co-design activities affects the co-design results, the differences of the behavioural pattern between the best- and worst-performed groups were presented using the LSA.

Relationships between behaviours and lesson design innovation in the co-design activities

With regard to the first research question on the relationship between behaviours and the innovation of lesson design in the co-design activities, the participants' behaviours during the co-design activities are presented in Table 2. Table 3 shows the quality of the innovation of the lesson design evaluated in terms of usefulness and originality.

As shown in Table 2, there was high engagement on the dimension group lesson design (G1) indicated by the high mean score (M = 9.37), followed by individual lesson design (I1, M = 3.6) and coordination (M = 1.9, 0.65), then finally by peer feedback (PF) and uptake (U) with lower mean scores (M < 1). This result could suggest that the behaviour group lesson design contributes to the quality of the lesson design innovation during the co-design process. The behaviour distributions suggest that participants had relatively more time and flexibility when engaging in lesson design and group actions related to task coordination. The low use of peer feedback and uptake suggests that participants did not spontaneously engage in peer interaction related to providing feedback to others and assimilating feedback from others without any scaffolds. In addition, as the descriptive statistics on the usefulness and originality, participants' lesson designs were of medium innovation (the possible full score was 7).

Table 2
Means and standard deviations of behaviours during co-lesson design

Dimension	Behaviour codes	*M*	*SD*
Coordination	C1	1.92	2.59
	C2	0.65	0.80
Group lesson design	G1	9.37	15.89
Individual lesson design	I1	3.6	3.55
Peer feedback	PF1	0.07	0.31
	PF2	0.75	1.05
	PF3	0.63	1.10
	PF4	0.47	1.24
	PF5	0.07	0.25
Uptake	U1	0.23	0.53
	U2	0.25	0.68
	U3	0.1	0.40
	U4	0.13	0.54

Note. The mean score (*M*) is the average of each behaviour and dimension of innovation. The standard deviation (*SD*) is the differences in values of each variable among participants.

Table 3
Means and standard deviations of the quality of innovation of lesson design

Dimension	Innovation type	*M*	*SD*
Innovation	Usefulness	4.45	1.36
	Originality	4.45	1.26

Correlation analyses
To understand the impact of the co-design behaviour on the quality of the innovation of the lesson design, we employed correlation analysis (Table 4). The results showed that behaviours of I1 (individual lesson design) were positively related to participants' innovation of lesson design in the usefulness dimension. In contrast, PF2 (peer feedback: clarification) was negatively related to participants' innovation of lesson design in both dimensions of usefulness and originality. In addition, PF4 was also negatively related to participants' innovation in lesson design in the usefulness dimension. These results suggested that when the participants added more information to their own lesson designs, their lesson design were more innovative from the dimension of usefulness. However, when more clarifications through feedback were given to the participants, the innovativeness of the lesson design declined in both the dimensions of usefulness and originality.

Table 4
Correlation and regression between behaviours and the innovation of lesson design

Code	Correlation analyses		Regression analyses	
	Usefulness	Originality	Usefulness	Originality
C1	0.164	0.092		
C2	-0.109	-0.18		
G1	-0.132	-0.14		
I1	$.433^{**}$	$.279^{*}$	0.515^{***}	
PF1	-0.091	-0.032		
PF2	$-.427^{**}$	$-.481^{**}$	-0.362^{**}	-0.481^{***}
PF3	-0.063	-0.091		
PF4	0.084	0.169	-0.298^{*}	
PF5	0.158	0.109		
U1	-0.077	-0.1		
U2	0.114	0.05		
U3	0.071	0.149		
U4	0.009	0.079		

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Stepwise regression analyses
Furthermore, we employed stepwise regressions to identify the significant predictors for their innovation of lesson designs in terms of usefulness and originality. Participants' behaviours were included in the initial regression model (Table 4). The behaviour of I1 (individual lesson design) significantly positively predicted participants' innovation of lesson designs in terms of usefulness, whereas PF2 (peer feedback: clarification) and PF4 (peer feedback: positive affection) were significantly negatively predicted. Regarding originality, only PF2 could significantly negatively predict it.

Taken together, the results of correlations and regressions suggested that the more individual lesson design should be encouraged during co-design of lessons as it promotes increase in innovation from the dimension of usefulness. In contrast, innovativeness from the dimensions of usefulness and originality could not be advanced via clarification through peer feedback.

Behavioural patterns

To address our second research question on behavioural patterns, we put the behavioural sequences by all groups into GSEQ.

Overall behavioural patterns of all groups

The frequency and adjusted residual results were automatically calculated by GSEQ (Tables 5 & 6). Behaviour transition diagrams and all sequences that reached statistical significance are shown in Figure 1. There were 33 significant behavioural sequences.

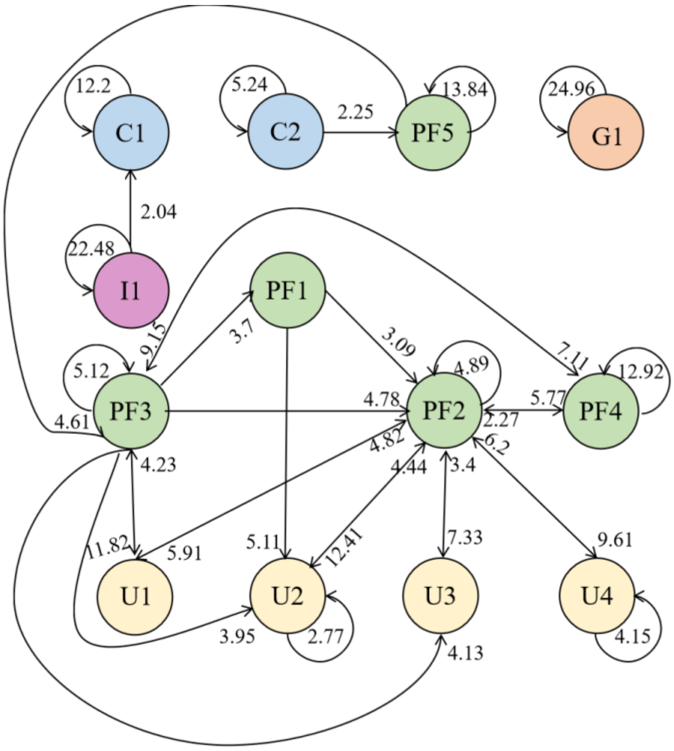

Figure 1. *Statistically significant behavioural sequences*

Behavioural path I1 → C1 (Individual lesson design → coordination) showed that after participants finished their own design, they usually sought coordination with other group members. Behavioural paths PF2 → U1, PF3 → U1, and PF2 → U3, PF3 → U3 showed that after a group received clarification or suggestion feedback of participants from other groups, the group copied the feedback with or without revising their lesson designs. The results suggested that the transitions of U1 (copy) and U3 (copy without revision) were similar. However, the transitions were different in U2 (apply) and U4 (apply without revision). They had the same behaviour path from PF2 (PF2 → U2, and PF2 → U4), but for U2, two unique behavioural paths were found. The transitions from PF1 and PF3 to U2 showed that after a group received peers' judgements and suggestions, group members applied the feedback to revise their lesson designs. Compared with the copy behaviours (U1 and U3), it is worth mentioning that PF1 was unique for applying peer feedback to revise the lesson designs.

Differences in behavioural patterns between the best-performed group and worst-performed group

Furthermore, to understand the different behaviour paths between groups of best and worst performance on their innovation of lesson designs, LSAs were conducted respectively for the two selected groups. The best-performed group is Group A and included four members ($M_{\text{usefulness}} = 5.63$, $M_{\text{originality}} = 5.50$). The least performance group is Group B and included three members ($M_{\text{usefulness}} = 0$, $M_{\text{originality}} = 0$).

We put group behaviour sequences into GSEQ. In Group A, we found the significant transitions of I1 → I1 and G1 → G1. The results suggested that group members both concentrated on completing their own lesson design and co-design (Table 7). However, Group B showed different behavioural patterns. We found six significant transitions, that is, C1 → C1, G1 → G1, PF2 → PF4, PF2 → U1, PF4 → PF4, and U1 → PF3. These behavioural patterns suggested that Group A focused more on leading task coordination or guiding group actions; furthermore, after participants received clarification and positive affection from peers, they tended to copy these ideas from the feedback (Table 8). Based on LSA, the main difference between the two groups was that Group A concentrated more on completing their own lesson design and co-design, whereas Group B tended to copy ideas, including in peer feedback.

Table 5
Results of frequency transition of all groups

N	C1	C2	G1	I1	PF1	PF2	PF3	PF4	PF5	U1	U2	U3	U4	Totals
C1	47	5	37	30	0	3	0	0	0	0	0	0	0	122
C2	1	7	20	4	0	3	0	0	1	0	0	0	0	36
G1	27	24	564	14	0	5	10	3	0	0	0	0	0	647
I1	28	5	14	173	1	4	1	0	1	0	1	0	0	228
PF1	0	0	0	0	0	1	0	0	0	0	1	0	0	2
PF2	1	0	2	1	0	10	4	8	1	5	13	4	6	55
PF3	0	0	0	1	1	8	7	8	0	8	4	2	0	40
PF4	0	0	2	2	0	4	10	12	0	0	0	0	1	31
PF5	0	0	0	0	0	1	2	0	2	0	0	0	0	5
U1	0	0	3	1	0	4	3	0	0	0	1	0	0	12
U2	3	0	9	0	0	5	1	0	0	0	2	0	0	20
U3	0	1	1	1	0	2	1	0	0	0	0	0	0	6
U4	0	1	0	1	0	4	1	0	0	0	0	0	1	8
Totals	107	43	652	228	2	55	40	31	5	13	22	6	8	1212

Note. The number 27 in row 2, column 3 means that "C1 occurring immediately after G1" happened 27 times.

Table 6
Results of sequential analysis for the behaviour of all groups

Z	C1	C2	G1	I1	PF1	PF2	PF3	PF4	PF5	U1	U2	U3	U4
C1	12.2	0.35	-5.47	1.73	-0.47	-1.16	-2.15	-1.89	-0.75	-1.21	-1.58	-0.82	-0.95
C2	-1.3	5.24	0.22	-1.2	-0.25	1.11	-1.12	-0.99	2.25	-0.63	-0.83	-0.43	-0.5
G1	-6.1	0.33	24.96	-15.85	-1.51	-6.73	-3.65	-4.94	-2.4	-3.88	-5.06	-2.63	-3.03
I1	2.04	-1.23	-16	24.48	1.13	-2.24	-2.68	-2.71	0.07	-1.74	-1.73	-1.18	-1.37
PF1	-0.44	-0.27	-1.53	-0.68	-0.06	3.09	-0.26	-0.23	-0.09	-0.15	5.11	-0.1	-0.12
PF2	-1.87	-1.46	-7.63	-3.3	-0.31	4.98	1.69	5.77	1.67	5.91	12.41	7.33	9.61
PF3	-2	-1.23	-6.93	-2.68	3.7	4.78	5.12	7.11	-0.41	11.82	3.95	4.13	-0.52
PF4	-1.75	-1.08	-5.35	-1.78	-0.23	2.27	9.15	12.92	-0.36	-0.59	-0.77	-0.4	1.79
PF5	-0.7	-0.43	-2.42	-1.08	-0.09	1.67	4.61	-0.36	13.84	-0.23	-0.3	-0.16	-0.18
U1	-1.08	-0.67	-2.01	-0.93	-0.14	4.82	4.23	-0.56	-0.22	-0.36	1.7	-0.25	-0.28
U2	0.98	-0.86	-0.79	-2.17	-0.18	4.44	0.43	-0.73	-0.29	-0.47	2.77	-0.32	-0.37
U3	-0.76	1.74	-1.83	-0.13	-0.1	3.4	1.84	-0.4	-0.16	-0.26	-0.33	-0.17	-0.2
U4	-0.88	1.37	-3.06	-0.46	-0.12	6.2	1.46	-0.46	-0.18	-0.3	-0.39	-0.2	4.15

Note. The number in the table refers to Z scores. When the Z score of a sequence is greater than 1.96, it indicates the sequence reaches a level of significance ($p < .05$). For example, the number 2.04 from the C1 column and I1 row means that "C1 occurring immediately after I1" is significant.

Table 7
Results of sequential analysis for behaviour in Group A

Z	I1	G1	C1
I1	9.57	-9.56	1.96
G1	-10.14	10.26	-2.3
C1	3	-.23	1.03

Table 8
Results of sequential analysis for behaviour in Group B

Z	C1	C2	G1	PF2	PF3	PF4	U1
C1	2.54	-0.37	-0.66	-0.3	-0.21	-0.3	-0.3
C2	-0.32	-0.32	0.71	-0.26	-0.18	-0.26	-0.26
G1	-0.91	0.74	3.41	0.6	-2.4	-3.42	-3.42
PF2	-0.26	-0.26	-3.57	-0.21	-0.15	4.74	4.74
PF3	-0.18	-0.18	-2.51	-0.15	-0.1	-0.15	6.82
PF4	-0.26	-0.26	-1.5	-0.21	-0.15	4.74	-0.21
U1	-0.26	-0.26	-1.5	-0.21	6.82	-0.21	-0.21

Discussion and conclusion

This study examined how pre-service teachers' behaviours affected their innovations of lesson designs in co-design activities. Research has mainly focused on how teacher education programmes affect their knowledge, attitudes and beliefs of technology integration from the technological pedagogical and content knowledge framework and has paid less attention to pre-service teachers' instructional innovation with ICT (Birisci & Kul, 2019; Farjon et al., 2019; Koehler et al., 2007; Wilson et al., 2020). However, ICT not only can act as supporting old instruction but also innovate instruction, such as changing the delivery of curriculum content, the instructional process and the ways of teacher-student interaction (Cole & Weber, 2019; Shear et al., 2014; Wong et al., 2008). Co-design represents an emerging approach within the learning sciences for producing more usable innovations to improve teaching and learning (Severance et al., 2016). There is little evidence regarding the effects of pre-service teachers' behaviours in co-design activities on their instructional innovations. The current study addressed the issue by analysing the relationships between pre-service teachers' behaviours in co-design activities and their innovations in terms of usefulness and originality by correlation and step regression analyses, as well as LSA. Overall, this study yielded two major findings.

Firstly, this study found that behaviours of engagement into individual ideation and within-group ideation in co-design activities was positively related to pre-service teachers' innovations of lesson designs (i.e., usefulness and originality). The best-performed group concentrated more on individual ideation and within-group ideation in co-design activities rather than coordination or peer feedback by LSA. A possible explanation is that because of the limited time of co-design activities and the limited cognitive resources, they had to engage in individual ideation, group ideation, giving feedback to their peers, and elaboration of their lesson designs based on peer feedback. As a consequence, they did not have enough time and cognitive resources to deeply process and think over peers' lesson designs and feedback. Therefore, they could not benefit from the process of giving feedback to peers and receiving feedback from peers.

An alternative explanation was that students lacked the ability to build on peers' lesson designs through giving feedback. Studies have shown that students do not spontaneously build on peers' ideas, which is considered to play an essential role in collaborative learning (Barker, 2015; Sangin et al., 2008). Other studies have shown that there were many factors influencing group members' combination process, including collaborative process settings (e.g., the source of peers' ideas, the group context, the quality of peers' ideas and the phase of the combination process) and group members' individual characteristics (e.g., the level of openness, the level of creativity; Michinov et al., 2015; Pi et al., 2019). For example, a study conducted by Kohn et al. (2011) found that after group members' individual ideation, they could elaborate more on peers' ideas than those without the process of individual ideation in interactive groups. Research is needed to further investigate how to improve the effectiveness of the combination process during co-design activities.

Secondly, this study found that pre-service teachers' behaviours of giving feedback to peers and receiving feedback from peers played important roles in lesson design innovations. Specifically, the clarification type and positive affection type of peer feedback was negatively related and predicted their innovations, and the worst- performed group tended to directly copy information from peer feedback. Studies on uptake have shown that whether group members are able to apply and integrate information provided by others into their ongoing work appears to be crucial for their learning (van de Pol et al., 2019). By applying the information provided, students are better able to continue working constructively and extend and deepen their understanding (Wittwer et al., 2005; Wittwer & Renkl, 2008). As opposed to applying information, not understanding or copying information provided results in an illusion of understanding (Chi, 2000; van de Pol et al., 2019). In this study, when pre-service teachers clarified peers' ideas, they might not have understood the information to be learned. As a result, they continued working in their own way and did not incorporate the accessible information included in the peers' ideas in their ongoing lesson design. When pre-service teachers copied the information included in peer feedback, they commonly used the explanation from the feedback to come to an answer but without discussing it or thinking deeply; they merely copied the explanation into their lesson designs. Therefore, when clarifying peers' ideas or copying peer feedback, pre-service teachers did not integrate the peers' lesson design or feedback into their existing knowledge scheme. Based on the results of the current study, clarifying peers' ideas or copying peer feedback was expected to be less beneficial to their instructional innovation with ICT.

The main limitation in the present study is that we did not test the long-term effects of pre-service teachers' behavioural patterns in co-design activities on their future instructional innovations with ICT. Several longitudinal studies have explored the long-term effects of technology integration courses (Hofer & Grandgenett, 2012; Milman & Molebash, 2008). Providing a deeper look into the change may allow for more predictive conclusions. Furthermore, exploring the impact of co-design activities as the pre-service teachers transition into practice would help educational technologists operating in the domain of teacher education better decide how best practice now impacts teacher instructional innovations practice later.

Despite the above limitations, the findings of this study contribute to the literature on teacher education programmes for technology integration and instructional innovation with ICT. The value of this study is to test how pre-service teachers' behaviours during co-design activities affected their instructional innovations with ICT. Moreover, this study proposed a coding scheme for co-design activities, which could be an alternative tool for concentrating on how group members engaged in co-design activities. Studies on collaborative learning have proposed coding schemes with greater emphasis on knowledge construction (Y. Chen et al., 2009; Hou & Wu, 2011). The value of the proposed coding scheme is that it focuses on timely interaction behaviours among group members for co-design activities, with some code items focused on coordination and some on knowledge construction. The items along with the LSA could reveal group coordination patterns in detail, which could be a potential tool for future research related to co-design activities.

In conclusion, this study found that pre-service teachers' who more concentrated on individual ideation and group ideation benefited more than those who gave feedback of clarification to their peers and copied the information from peers' feedback during co-design activities. The findings confirmed the role of engagement in individual ideation, within-group ideation, and feedback in pre-service teachers' innovations in an authentic teacher education programme. The results provided further evidence of how pre-service teachers engaging in co-design activities affect their instructional innovations with ICT and they have practical implications for educational practices: pre-service teachers are encouraged to concentrate on individual ideation and group ideation; furthermore, they are not encouraged to copy from their peers' feedback.

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