Ordering Effects in a Role-Based Scaffolding Intervention for Asynchronous Online Discussions*

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Abstract. A common scaffolding approach in computer-supported collaborative learning is the assignment of specific roles to the participants in online asynchronous discussions. Previous work has demonstrated how this type of scaffolding can result in student contributions of greater depth and quality. However, since students necessarily experience the roles in varying orders, it is important to consider whether the ordering impacts the outcome. This paper addresses the issue by examining a scaffolding intervention that was deployed in an asynchronous online discussion forum, where students were assigned to lead the discussion in one thread as the 'expert' and to participate in other threads by asking questions. A network analytic approach was used to visualise and quantify several potential ordering effects within the intervention. The constructs of cognitive presence and cognitive engagement, from the Community of Inquiry and the ICAP frameworks, were used together to measure the depth and quality of the discussion contribution expressed in each message. The analysis confirmed that the contributions made while the student was in the 'expert' role scored significantly higher for both constructs, but found that the order in which students took on each role had little impact on the quality of their contributions to other threads. This result contrasts with earlier work on single-duty roles that found an advantage in being assigned certain roles early in the discussion, and suggests that instructors should feel confident in rotating more complex user roles between students.

Keywords: Online discussion · Scaffolding · Critical thinking · Student engagement · Learning analytics · Community of Inquiry · Cognitive presence · Cognitive engagement · Epistemic Network Analysis

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1 Introduction

Asynchronous online discussion forums are a common feature in virtual learning environments. Stand-alone discussion platforms such as Piazza[3] are also used to manage students' questions, in both online and classroom-based courses. The discussions that take place in these forums can help to build a sense of community among learners [6] – particularly important when in-person interaction was severely restricted due to a global pandemic. Time-stamped transcripts of the messages that are exchanged can also be used to inform research into how effective learning takes place through discussion.

Research in computer-supported collaborative learning (CSCL) has shown that participation in asynchronous discussions can be beneficial to participants, giving them opportunities to increase the depth of their own cognitive engagement through collaborative knowledge construction [12,13,14] as well as fostering social belonging [6]. However, in order to achieve these benefits, it is often necessary to provide explicit guidance in the form of scaffolding [11,15,18]. Prior work [26] suggests that when students are assigned a role that requires them to summarise the contributions of others, there is a positive effect on their breadth of listening while they are 'in-role', but the effect is not sustained afterwards. Other studies [7,21] have suggested that the timing of role assignment can impact outcomes, with earlier assignment seen as more beneficial for some roles.

The depth and quality of student participation in asynchronous online discussions has been examined and quantified using many different theoretical frameworks (*e.g.* Bloom's Taxonomy [2], the SOLO taxonomy [1], The Community of Inquiry framework (CoI) [13,14], and the Interactive-Constructive-Active-Passive (ICAP) framework [3]). Of these, only CoI was designed specifically for the online context. Most previous studies have focused on a single framework, while a few have used a combination of two or more in order to provide a richer, multi-dimensional analysis of the data [8,9,19,22].

The specific type of scaffolding intervention considered in this work is an approach centred on assigning 'roles' to discussion participants. The study presented here investigated how the effect of the role-based scaffolding was moderated by the order in which participants experienced the different roles. Messages were classified using both the *phases of cognitive presence* from CoI and the *modes of cognitive engagement* in ICAP.

2 Background

2.1 The Community of Inquiry Framework

The Community of Inquiry (CoI) framework defines three 'presences' that support learning in an online community: *social presence*, *teaching presence*, and *cognitive presence* [14]. Of these, cognitive presence is considered to be the most fundamental to educational success. Discussions are expected to progress through

[3] https://piazza.com

its four phases (*Triggering Event*, *Exploration*, *Integration*, and *Resolution*) over time (Table 1), and the phases have been used as a measure of the depth and quality of student participation in asynchronous discussions [8,9]. In the ideal case, a discussion would start with a *Triggering Event* that defines the problem, move through an *Exploration* phase where new ideas are considered, then bring some of those ideas together in the *Integration* phase, and finally achieve consensus on a solution in the *Resolution* phase. In reality, progression through the phases is seldom linear. Many discussions do not reach the *Resolution* phase.

Table 1. The four CoI phases of cognitive presence in ascending order, plus the *Other* label, which can be used where a message does not display any cognitive presence.

Short label	Phase of cognitive presence	Example behaviour
TRIG	Triggering Event	Asking a question or posing a problem
EXP	Exploration	Exchanging ideas
INT	Integration	Integrating ideas and constructing meaning
RES	Resolution	Reaching consensus or suggesting a new hypothesis
OTH	*Other*	Commenting with no sign of cognitive presence

2.2 The ICAP Framework

The ICAP framework [4] has been used widely, in classroom-based studies as well as online. It defines four modes of cognitive engagement, based on observable student behaviours: **I**nteractive, **C**onstructive, **A**ctive, and **P**assive. Each mode represents a qualitatively different type of knowledge growth. Interventions and activities that targeted the higher modes of cognitive engagement were shown to achieve greater learning gains. Several recent studies adapted and expanded the original framework [8,9,25,28] in the context of asynchronous online discussions. The *Constructive* and *Active* modes were each subdivided and messages of *Affirmation* were treated separately (Table 2).

3 Research Question

Previous studies have shown how external scripts such as assigned roles can help students to develop skills relating to collaboration and social knowledge construction [7,11,21,24,27]. However, there is some evidence that the effects may not persist after the intervention has ended [26]. Some roles have been shown to be particularly beneficial to those who take them on (*e.g.* 'summarizer' [21]). Other single-duty roles have been shown to be detrimental to learning (*e.g.* 'source-searcher' [7]) when used in isolation. It is therefore seen to be important to rotate single-duty roles among students and to consider the use of composite

Table 2. The extended set of ICAP modes of cognitive engagement in descending order, plus the *Off-task* label, used for messages displaying no cognitive engagement.

Short label	Mode of cognitive engagement	Example behaviour
I	Interactive	As for **C1**, in response to earlier message content
C1	Constructive Reasoning	Displaying explanation or reasoning about the current topic
C2	Constructive Extending	Introducing new content to the discussion
F	Affirmation	Affirming what was said in an earlier message
A1	Active Targeted	Referencing specific previous content
A2	Active General	Showing other signs of being engaged with content
P	Passive	Reading messages without responding
O	*Off-task*	Commenting with no relation to the topic/ course

roles that combine several lower-level duties [15,27]. The timing of role assignment has also been seen to impact learning outcomes [7]. There is thus a need for research into potential ordering effects within role-based interventions, since participants necessarily experience the roles in varying orders.

Earlier studies looked at the effects of role assignments using a single measure of the quality of knowledge construction [21], sometimes in combination with final exam scores [7]. Recent work has shown the benefits of integrating insights from multiple frameworks for analysing aspects of student participation in asynchronous discussion tasks [8,9,19,22]. The research question addressed in the present study was therefore:

RQ: *How do ordering effects between roles affect the depth and quality of student contributions to an asynchronous discussion task, as measured by both the CoI phases of cognitive presence and the ICAP modes of cognitive engagement?*

4 Method

4.1 Description of the Data

The role-based scaffolding intervention examined in this study was deployed in a credit-bearing distance-learning course in Software Engineering over six course offerings (2008–2011). The discussion task accounted for 10% of the course grade and helped students to develop their own research questions. Two complex user roles were defined, with students expected to take on both roles during the task.

- *Research Expert*: prepare and upload a presentation about a relevant research paper of their choice, then lead a discussion on its content on a dedicated thread in the discussion forum; and
- *Practising Researcher*: contribute to discussions about other students' presentation topics.

Both roles thus incorporated duties defined in earlier work as 'summarizer', 'source searcher', and 'theoretician' [7,21,27]. The *Research Expert* role additionally required the student to undertake 'moderator' and 'topic leader' duties.

The discussion task ran during weeks 3–6 of each course offering. Every student was expected to take on the *Research Expert* role once and the *Practising Researcher* role several times. Approximately one-third of the students took on the *Research Expert* role in each of the first three weeks of the task. The discussions that followed were asynchronous and ranged from 3 days to 27 days in duration. The median thread duration was 13 days. All discussion threads remained open until the end of the task. It was thus very common for a student to contribute to one or more threads as a *Practising Researcher* at the same time as they were acting as the *Research Expert* in their own thread.

In order to examine possible ordering effects in the present study, we considered two different ways of grouping messages by time, and another metric derived from those and intended to capture role order more directly (Table 3).

- **Thread Week**: The week within the discussion task when the message thread was started – even though the message itself may have been posted later. This allowed us to assess whether message quality changed when more time was available to contribute to a thread before the task ended.
- **Expert Week**: The week within the discussion task when the student who wrote the message started a discussion thread in the role of *Research Expert*. This allowed us to compare messages from students who experienced the *Research Expert* role at different times during the course.
- **Role Order**: The label *BeforeExpert*, *WhileExpert*, or *AfterExpert*, based on whether the Thread Week for the message was earlier, in the same week, or in a later week, compared with the Expert Week. This allowed us to assess the effects of role ordering more directly.

Table 3. Labels assigned to messages in threads where students A, B, C, and D took on the *Research Expert* role in the first, second, second, and third week, respectively.

Thread	Student	Thread Week	Expert Week	Role Order
Expert-A	B	1	2	*BeforeExpert*
Expert-B	C	2	2	*WhileExpert*
Expert-D	A	3	1	*AfterExpert*

Our analysis focused on the messages sent by students while they were in the *Practising Researcher* role, for two reasons: we wanted to distinguish potential role ordering effects from the large effect of the role assignment intervention itself [9,15]; and each student was only the *Research Expert* once. We excluded 9 messages that were sent by participants who never took on the *Research Expert* role, leaving 891 messages from 84 threads (Tables 4 and 5).

Table 4. Counts of unique participants, threads, and messages.

	Thread Week		Expert Week	
Week	Threads	Messages	Participants	Messages
1	32	352	26	346
2	30	288	30	312
3	22	251	22	233
Total	84	891	78	891

Table 5. Message counts in the Role Order groups.

	BeforeExpert	*WhileExpert*	*AfterExpert*	Total
Messages	310	304	277	891

Each message was assigned one label from each theoretical framework, based on its textual content. Two expert coders labelled the messages with the CoI phases of cognitive presence (Table 1), achieving high levels of agreement (98.1% agreement, Cohen's $\kappa = 0.974$). A second pair of independent coders assigned labels from the extended set of ICAP modes of cognitive engagement (Table 2), achieving 'substantial' inter-annotator agreement (Cohen's $\kappa = 0.623$) [17].

For the purposes of the present study, the *Interactive* and *Constructive Reasoning* labels were combined together and only *Constructive Reasoning* was used. The primary difference between them is that a message can only be labelled as *Interactive* if it is a direct response to the substantive content of a previous message (Table 2). While *Interactive* messages were relatively common for a *Research Expert*, there were limited opportunities for a *Practising Researcher* to interact in such a way during the discussion task presented in this study.

4.2 Epistemic Network Analysis

Epistemic Network Analysis (ENA) [23] is a network analytic approach that is designed for analysing the *connections between* small sets of concepts in a densely connected network. It allows sub groups to be compared both visually and statistically, and has been widely used in studies of online discussions [16,29] in general, and specifically for the constructs of cognitive presence and social presence in a Community of Inquiry [10,19,20].

Co-occurrences of labels in the data are used to construct a high-dimensional concept network. The *conversation* parameter defines which connections are included in the analysis. The network is projected down onto the two most informative dimensions, while maintaining the mathematical relationships between concepts, using *singular value decomposition*. The relative positions of the concept nodes in the resulting *projection space* makes the space itself interpretable, because concepts that share a pattern of connections will tend to be located close together [23]. A single point in the projection space represents the weighted mean of the connections in one sub-network, defined by the *unit of analysis* parameter. For example, this could be all the messages in a thread.

In the present study, we set the conversation parameter to be a single message. This meant that the only connections included in the network were the pairs of labels from the two theoretical frameworks: one label from the CoI phases of cognitive presence and one from the ICAP modes of cognitive engagement. We first grouped the messages by student and thread, so that all the messages sent by the same student in a single thread were aggregated together. As we looked at the order-based groupings in turn, the messages were aggregated further.

To become familiar with the general associations between the individual CoI phases of cognitive presence and the ICAP modes of cognitive engagement in this data set, we first explored the overall mean network based on all the messages sent in both roles. Noting the locations of the nodes in the overall mean network allowed us to interpret the space in terms of the framework constructs. The same projection space was subsequently reused for the analyses of messages sent by *Practising Researcher*s, broken down by each of the different groupings (Thread Week, Expert Week, and Role Order). The messages were aggregated by student, thread, and group to create the data points for each network. We used Mann-Whitney tests to determine whether pairs of groups were significantly different along either of the two axes of the projection space.

5 Results

Figure 1 shows the average ENA network across all messages. The framework constructs are shown using their short labels (Tables 1 and 2) to reduce visual clutter. The X axis accounts for 21.7% of the variance in the data and the Y axis accounts for 20.2%. The X axis primarily distinguishes between the early phases (*Triggering Event* and *Exploration*) and the later (*Integration*) phase of cognitive presence, while the Y axis distinguishes linearly between the three highest ICAP modes of cognitive engagement. The direct effect of the role assignment intervention is clearly visible. The points representing messages sent by students in the *Research Expert* role are all found toward the upper left of the plot, in the vicinity of the *Constructive Reasoning* (**C1**) node. In contrast, the messages sent by those in the *Practising Researcher* role are dispersed throughout the projection space, with the group mean near the centre of the plot.

Figure 2 shows the projection networks comparing messages sent by *Practising Researcher*s, aggregated by Thread Week, Expert Week, and Role Order. These networks all use the same projection space as Figure 1. The axes account for slightly less of the variance in the data: 21.1% for the X axis, and 20.1% for the Y axis. In each case, the group means appear close together, indicating that any differences are small. A series of Mann-Whitney tests showed that there were no statistically significant differences at the $\alpha = 0.05$ level between any of the Thread Week values in Figure 2(a). In addition, *ExpertWeek1* and *ExpertWeek2*

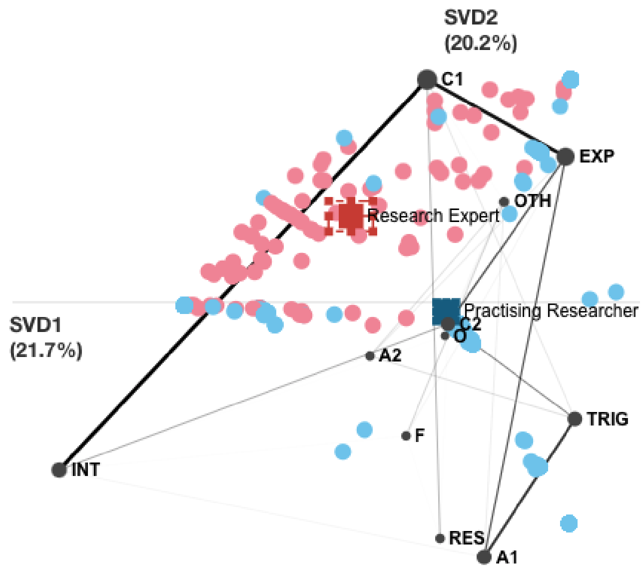

Fig. 1. ENA network constructed by aggregating the label co-occurrences within the messages sent by each student in each thread across both user roles. The positions of the black nodes indicate the locations of each framework construct in the two-dimensional projection space. Edge thickness indicates connection frequency. The pale blue and pale red points indicate the weighted mean of each student's messages: blue for *Practising Researcher*s and red for *Research Expert*s. Group means are shown as squares in darker blue and red respectively, labelled with the relevant user role.

were not significantly different from each other in Figure 2(b). The small difference seen between *ExpertWeek2* and *ExpertWeek3* along the Y axis was not considered significant after Bonferroni correction. However, *ExpertWeek3* was significantly different at the $\alpha = 0.05$ level along the Y axis (V2) from *ExpertWeek1* ($U = 24809.00$, $p = 0.0007$, $r = 0.18$). This indicates that students who were in the last group to take on the *Research Expert* role tended to contribute to other threads at a lower level, as measured by the ICAP modes of cognitive engagement, compared to their counterparts in the first group. The effect size is small [5]. There was no significant difference along the X axis.

Considering the effect of Role Order in Figure 2(c), a series of Mann-Whitney tests confirmed that, after Bonferroni correction, the only statistically significant difference between the groups was between the *AfterExpert* group and the the *BeforeExpert* group along the Y axis ($U = 29967.00$, $p = 0.0094$, $r = 0.13$). This indicates a small effect size for Role Order, corresponding to a tendency for students to demonstrate higher levels of the ICAP modes of cognitive engagement in threads that were started in the week(s) after their own expert thread, compared with the threads that were started in the week(s) before their own.

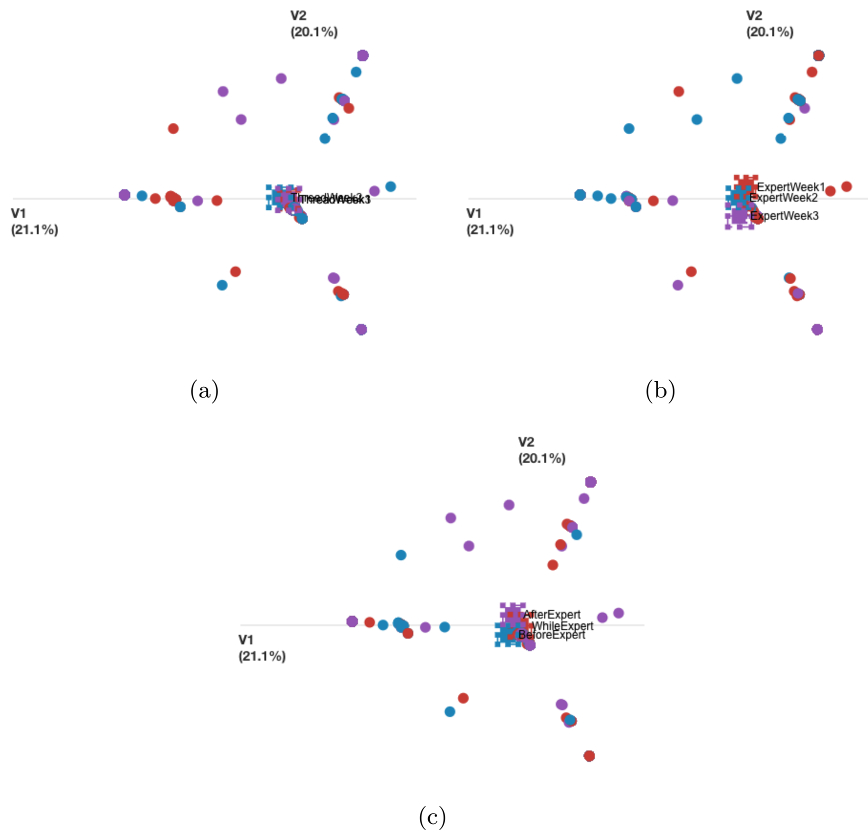

Fig. 2. ENA networks constructed using the messages sent in the *Practising Researcher* role, grouped by (a) Thread Week, (b) Expert Week, and (c) Role Order, in addition to student and thread. The points are coloured according to the relevant group: (a) the week within the task when the thread started; (b) the week within the task when the message author started acting as *Research Expert*; (c) the Role Order label. In both (a) and (b), week 1 is shown in red, week 2 in blue, and week 3 in purple. In (c), *BeforeExpert* is shown in blue, *WhileExpert* is in red, and *AfterExpert* is in purple. Group means are labelled and shown as squares in the appropriate colour.

6 Discussion

The results of this study confirmed the ability of a role-based scaffolding intervention to effect positive change, as seen in previous work [9,15] where messages sent by students in the *Research Expert* role achieved greater depth on both the CoI and ICAP frameworks, compared with those sent by students in the *Practising Researcher* role. However, there was little evidence of ordering effects. No significant differences were found between the message threads that were started in the first week of the activity compared to those in the final batch, despite the much longer time available for students to develop a deeper discussion.

The students in the present study were always assigned to a role, and these were composite roles that incorporated several of the low-level single-duty roles investigated in previous work. We noted a small effect where the group of students who were last to take on the *Research Expert* role demonstrated lower cognitive engagement in their contributions to other threads. One explanation for this could be that the effort of leading their own thread in the final week, while also ensuring that they had fulfilled the participation requirements, led to shallower engagement. Another potential explanation is the timing effect found in prior work [7], where a cohort that began without roles and had them assigned later performed worse than a cohort that had roles from the beginning. It is possible that the group who took on the *Research Expert* role last did not fully engage with the *Practising Researcher* role earlier.

A small effect was also found in the analysis of Role Order. Students in the *Practising Researcher* role, contributing to threads that started in the weeks after their own *Research Expert* thread started, scored higher on the ICAP modes of cognitive engagement. This could be because those students had time to devote to asking deeper questions, having finished with their own presentation. It could also be because they had learned from the experience of being in the *Research Expert* role and used this knowledge in later situations [7].

Since the discussion task in the present study only ran for four weeks, we were not able to discover any longer-term effects on behaviour. Analysis of discussions that took place over a longer period could produce different results, as participants grow in confidence and develop their skills, or perhaps become disengaged. The nature of the discussion task meant that students were often managing both roles in parallel: leading their own thread as a *Research Expert*, while at the same time contributing to other threads as a *Practising Researcher*. More specific instructions were given to participants in the later course offerings regarding the minimum contribution expected from students in the *Practising Researcher* role. The present study did not distinguish between those cases.

7 Conclusion

In the role-based scaffolding intervention presented in this study, the effects of role order were found to be small – especially in the context of the large primary effect of the intervention in improving student contributions according to two separate measures of depth and quality. This result suggests that instructors should feel confident in assigning complex roles and rotating them between students, without being afraid that a particular ordering might lead to disadvantage. Since the discussion task in the present study was relatively short in duration, future work should look at behaviour over the longer term, and in particular at examples where students repeat a similar style of task over time. It would also be valuable to directly contrast the use of single-duty roles with composite roles like those used here.

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