Preservice Teachers' Perspectives on Modelling and Explaining in STEM Subjects

A Q Methodology Study

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Teacher modelling and explaining are important pedagogical approaches in practical subjects, including those categorised as science, technology, engineering and/or mathematics (STEM). Building on a framework developed from research on 'the demonstration' with teachers and teacher educators of design and technology (D&T), this study explores preservice teachers' views across a range of secondary school subjects. This study is a snapshot of the evolving perspectives of the participants, early in their studies as students during initial teacher education (ITE). It uses Q Methodology to investigate the subjective values of preservice teachers towards teacher modelling and explaining. Q Methodology compares and analyses the responses of participants to a set of statements representing a range of possible views on a given subject. The sample is purposive, comprised of students enrolled on postgraduate ITE programmes with a Higher Education Institution (HEI) in England. The findings suggest that preservice teachers of STEM subjects strongly identified with one of two architypes – teacher-expert or teacher-facilitator. The paper concludes that preservice teachers of STEM should be made aware of these powerful architypes, when planning, teaching and evaluating lessons. The findings also suggest the possibility of collaborative training with preservice teachers across the STEM disciplines, using the statements from this study as a tool for dialogue. Future research could explore similarities and differences between practical/creative and humanities subjects.

Keywords: Practical Education; Q Methodology; STEM; Teacher Modelling and Explaining.

Introduction

This paper builds on the previous studies by McLain (2018, 2021) on the 'demonstration' as a signature pedagogy in D&T. The population sampled were postgraduate secondary preservice teachers, from a wide range of subjects, but excluding D&T. Participants were asked to sort and prioritise a set of statements related to teacher modelling and explaining, following a lead lecture on the topic. The findings presented in this paper focus on a smaller group of participants, where there was a stronger representation of students studying to teach STEM subjects; which includes biology, chemistry, computing, mathematics and physics, but neither D&T nor engineering preservice teachers, in this study. This paper concludes that there are similar patterns in responses from STEM preservice teachers as those of experienced teachers of D&T in an earlier study.

Literature Review

There has been recent interest in teacher modelling and explaining through Kirscher, Sweller and Clark's (2006) work on Direct Instruction (DI), from a cognitive science perspective, and Sherrington's (2019) booklet expounding Rosenshine's Principles of Instruction (2012). Similarly, Collins et al.'s (1991) cognitive apprenticeship framework identifies modelling and explaining as key methods in the teacher's repertoire.

Although Kirscher, Sweller and Clark's work promotes DI over more constructivist approaches, both Rosehshine and Collins et al. take a broader perspective on teaching; seeing the more direct methods of modelling and explaining within the wider context of learners' application of knowledge. In this context, modelling and explaining are interrelated and often indivisible. Modelling focusing on the visual/kinaesthetic demonstration and explaining the verbal articulation of a concept or process; both being concerned with making thinking explicit, emphasising sequence and connectivity. For a more thorough analysis of literature relating to teacher modelling and explaining, see McLain (2018, 2021).

McLain's (2018) study of D&T teachers' views on demonstration found one group (factor) with similar views. This group of experienced D&T teachers, using an earlier version of the statements used in this study (Table 4), considered the teacher's subject competence the most important aspect of an effective demonstration, supported by skilful classroom management. The statements relating to consolidation of learning and facilitation of independence were ranked lower, suggesting that demonstration alone was considered insufficient to promote a broader experience of the subject; albeit efficient and effective for transferring skills to novice learners. On an expansive/restrictive continuum of pedagogical methods, modelling and explaining (in the form of demonstration) were viewed as more restrictive; supporting the assertion above.

The follow up study by McLain (2021) developed this research with D&T teacher educators, presenting similar findings. This study identified two groups (factors), labelled as 'the teacher as expert' and 'the teacher as facilitator', reinforcing the proposal that demonstration tends to be viewed as a more teacher-centric and, therefore, more restrictive pedagogical method. Considered alongside two of the common psychomotor domains of learning objectives, the demonstration seems well suited to support learners in the transition from Dave's (1967) Imitation and Manipulation stages and Simpson's (1972) Perception, Set and Guided Response. There are also clear parallels with the early stages of DI (Adams & Engelmann, 1996; Hattie, 2008), which are followed by *guided* and *independent* practice. This is similar to how demonstration is commonly used in D&T to lead onto practical work, such as focused tasks or designing and making.

The demonstration is also a common teaching method in science, with some similarities and differences to how it is used in D&T. King et al. (2015) discuss the affective aspects of demonstrations in science, including the "emotions of wonder and surprise… happiness [and] joy" (p.1886). The learners engagement with the scientific phenomenon being demonstrated. Lin, Hong and Chen (2013) identify the novelty of hands-on experiment as an important follow up to a demonstration that has aroused learners' attention. Whilst the effects and outcomes of demonstration in science and in D&T may differ, there is an important link between demonstration and practice. However, the affective impact of demonstration on learners appears to be more apparent in literature for science education.

This study compares the views of STEM preservice teachers on teacher modelling and explaining, including the aspect referred to in science and D&T as demonstration.

Research Design

The research question for this study was: What do preservice teachers of STEM subjects believe about effective teacher modelling and explaining and, in particular, demonstration? A hypothesis was that there would be a greater alignment between D&T and the wider group of 'practical' subjects (as described below) than that of the STEM suite of subjects.

This study was the third in a series of related studies using Q Methodology (Watts & Stenner, 2012), a research approach that explores participants' subjective beliefs to explore complex issues and gain novel insights. Q Methodology is a qualitative approach that uses quantitative methods to analyse participants' responses. Participants sort and rank a series of statements relating to a topic or issue, in a *forced-choice frequency distribution* along a continuum from 'most agree' to 'most disagree' (Figure 1, Stage 2), the responses of which are examined using factor analysis, comparing the participants with one another. The factor analysis identifies groups (factors) of participants with similar views.

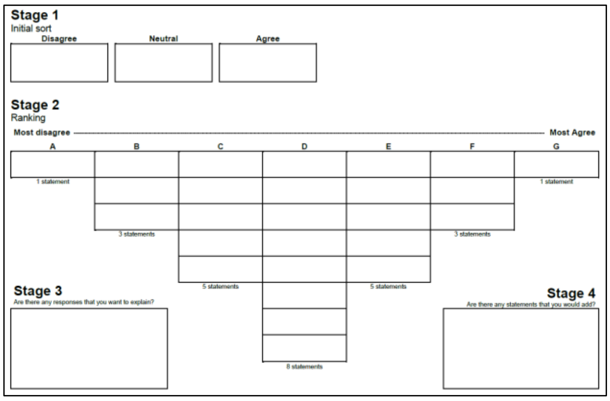

Figure 1. Participant Response Sheet

In this study, the views of preservice teachers in secondary subjects at a university-based ITE department, in England. The data was gathered during a workshop, which followed a lead lecture on teacher modelling and explaining (early in the first semester of studies, at the beginning of their first teaching placement). Participants sorted 26 statements refined from the previous studies on teachers' (McLain, 2018) and teacher educators' (McLain, 2021) views; both of which focused on design and technology educators. The original studies used a set of 62 statements (Q-Set). The factor analysis used in Q Methodology can identify two categories of statement, *consensus* and *distinguishing*, the latter of which from McLain (2021) were used to create the Q-Set for this study. The distinguishing statements were used to more easily elicit participants views and identify potential trends and patterns across groups – in particular in subjects classed as practical (especially STEM).

The data was gathered using the response sheet in Figure 1, with participants being asked to complete an initial sort (Stage 1) to determine general agreement/disagreement, followed by are more detailed ranking of the extent to which they agreed or disagreed with each individual statement (Stage 2). The participants were a convenience sample (Table 1), taken from the secondary postgraduate cohort at the institution where the study was conducted; comprised of preservice teachers on both a traditional university based programme and school-lead programmes (School Direct). The participants (n=192) are from 15 subject groups (and 4 primary specialists who participated in the activity), including 9 subjects classified as practical and 5 as STEM. The data were analysed using a software package, PQMethod (Schmolck, 2014), designed to analyse Q Methodology data.

Table 1. Participants by Subject

Subject	**No.**	**Practical?**	**STEM?**
Art and Design	10	Yes	
Biology	16	Yes	Yes
Chemistry	8	Yes	Yes
Computing	9	Yes	Yes
Dance	10	Yes	
Drama	4	Yes	
English	27		
Geography	16		
History	9		
Mathematics	24		Yes
Modern Languages	15		
Music	1	Yes	
Physical Education	31	Yes	
Physics	5	Yes	Yes
Primary	4		
Religious Education	3		
Total	**192**		

The ethical guidelines and practices of the host institution were followed when gathering research data for this study. Participants gave their consent for their responses to be used for research purposes and the responses sheets were anonymised, with no personal data being gathered or stored.

Findings

7 factors were extracted in the analysis, ranging in size from 6 participants (Factor F5) to 15 (Factor F7); where a factor is a group of participants with similar responses (Table 2). Of the 192 participants 81 were identified with one of the 7 factors.

Between 38% and 44% of most subject cohorts were represented in one of the factors. Two subjects - art and design (70%) and dance (70%) - were more strongly associated with a factor. Two subjects - physics (20%) and primary (25%) - were less strongly associated with a factor. And two subjects, music and religious education, were not associated with a factor. However, low or no association with a factor may be affected by the relatively small cohort sizes for the four subjects with fewer than a quarter of their cohort represented.

Table 2. Composition of Factors

Subject	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**Total**	**No.**	**%**
Art and Design		1	3			2	1	**7**	10	70%
Biology	2	1			1	1	1	**6**	16	38%
Chemistry	1			1	1			**3**	8	38%
Computing	1	2	1					**4**	9	44%
Dance	1	2		2			2	**7**	10	70%
Drama								**0**	4	0%
English	1	3	1	1	1	5	1	**13**	27	48%
Geography	1			2		2	2	**7**	16	44%
History			1		1	2		**4**	9	44%
Mathematics		4		2	1	1	1	**9**	24	38%
Modern Languages		1	1				4	**6**	15	40%
Music									1	0%
Physical Education	3		2	5	1	1	1	**13**	31	42%
Physics						1		**1**	5	20%
Primary	1							**1**	4	25%
Religious Education								**0**	3	0%
Total	**11**	**14**	**9**	**13**	**6**	**15**	**13**	**81**	**192**	**42%**

Considering the participants associated with a factor, three subjects (computing, history and modern languages) were more strongly represented with one factor (half or more). With a third or more participants represented, were art and design, biology, computing, English and physical education. Practical subjects comprised a higher proportion of participants in 5 factors, with STEM higher in one and equal in one (Table 3).

Table 3. Composition of Factors for STEM and Practical Subjects

Subjects	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
STEM	4 (36%)	7 (50%)	1 (11%)	3 (23%)	3 (50%)	3 (20%)	2 (15%)
Practical	8 (73%)	6 (43%)	6 (67%)	8 (62%)	3 (50%)	5 (33%)	5 (38%)

The Q-Set Statements

Table 4 shows the 26 statements, known as the Q-Set, which were refined from 62 statements in the previous studies (McLain, 2018, 2021). This Q-Set was based on the 'distinguishing' statements between the two factors in the 2019 study, and adapted for use across the full range of secondary subjects.

Table 4. Q-Set Statements

Q1. The teacher gives a brief overview of the content to be modelled/explained before starting.	Q2. The teacher refers to the application of the concept/process, which is being modelled/explained, outside the context of the lesson.	Q3. The teacher identifies any potential problems (e.g. hazards and risks) for the pupils when they are putting the knowledge/skill into action.
Q4. The teacher presents the learning aims/objectives/outcomes for a short demonstration within a lesson.	Q5. The teacher presents their expectations for how pupils will behave when a concept/process is being modelled/explained.	Q6. Appropriate information about potential problems (e.g. hazards and risks) is readily available to pupils in the lesson.
Q7. The teacher provides a running commentary through a demonstration.	Q8. The teacher makes connections with other related concepts/processes when modelling/explaining.	Q9. The teacher enables pupils to identify alternative actions or choices that they can make when applying a concept/process that they are modelling/explaining.
Q10. The teacher refers to the implications of any decisions and/or actions that pupils will make when applying the knowledge/skill being modelled/explained.	Q11. The teacher uses examples, analogies and/or similes to illustrate the concept/process that is being modelled/explained.	Q12. The teacher waits for pupils to attempt a task, where the concept/process has been modelled/explained in the lesson, before intervening.
Q13. The teacher identifies the main points/steps of a concept/process when modelling/explaining it.	Q14. The teacher 'signposts' or indicates the next steps for pupils after modelling/explaining a concept/process (i.e. “later in the lesson…” or “in next lesson…”).	Q15. The teacher prompts pupils to identify potential problems (e.g. hazards and risks) for themselves.
Q16. The teacher addresses pupils’ misconceptions as they arise whilst modelling/explaining.	Q17. The teacher uses questioning to probe learners’ prior knowledge from recent lessons when modelling/explaining a concept/process.	Q18. The teacher sets high standards and expectations for the pupils’ responses to activities following a concept/process being modelled/explained.
Q19. The teacher uses questioning to probe learners’ relevant prior knowledge from other subjects when modelling/explaining and new concept/process.	Q20. The teacher uses questioning to help pupils to recall knowledge from the modelling/explaining of a concept/process.	Q21. After an episode of teacher modelling/explaining and pupils are applying a concept/process, the teacher scans the room to monitor progress.
Q22. The teacher uses questioning to encourage pupils to speculate (e.g. to predict what might happen next in a process or infer an explanation to a new concept).	Q23. The teacher prepares and uses examples of the learning outcomes that pupils might produce (e.g. example sentences, actions, artefacts, etc.).	Q24. After a concept/process has been modelled/explained and pupils are applying the knowledge/skill, the teacher moves around the room to support pupils.
Q25. The teacher prepares examples to illustrate the steps/stages of a process being modelled/explained.	Q26. The teacher prepares the resources and area where they will be modelling/explaining, before the lesson.	

Factor composition

Table 5 shows the ranking of items for each of the 7 factors, with the Z-Score ranges indicated to show the extent to which participants agreed with each other.

Table 5. Factor Ranking (with Z-Score Ranges)

	Most Agree ---Most Disagree																									
F1	11	14	3	17	13	22	25	20	24	7	19	16	10	8	4	26	18	6	23	9	2	21	5	1	12	15
F2	11	8	24	2	13	25	9	22	26	1	17	20	5	16	19	12	10	23	14	3	4	21	18	15	6	7
F3	26	6	5	24	23	25	18	20	22	13	11	17	4	21	19	9	1	8	16	7	3	10	15	14	2	12
F4	18	17	22	20	24	19	3	12	21	13	5	26	16	9	8	1	25	11	14	15	6	4	2	23	10	7
F5	16	12	6	22	24	20	19	26	17	15	7	25	8	13	5	11	21	9	2	23	14	1	4	3	10	19
F6	18	7	20	24	13	11	26	17	16	1	8	22	25	23	5	2	19	21	9	14	4	12	10	15	6	3
F7	26	1	13	21	25	24	20	17	23	16	14	19	12	4	11	3	22	8	9	5	18	6	10	7	2	15

Key (Z-Score Range)	Top (+2) (>1.000)	High (+1) (1.1000 to 0.300)	Middle (0) (0.300 to -0.300)	Low (-1) (-0.300 to -1.000)	Bottom (-2) (<-1.000)

This paper will focus on Factors F2 and F5, both of which are comprised of 50% STEM preservice teachers (Table 3); although there will be value in exploring the other five factors in future analyses. F2 is the largest group (n=14) and F5 the smallest (n=6). The gender balance in both groups was equal.

Note: in Q Methodology the groupings of participants with similar responses are known as ‘factors’.

Factor 2: learning as a continuum led by the teacher

Factor 2 is comprised of one art and design, one biology, two computing, two dance, three English, four mathematics and one modern languages students. This group were focused on knowledge or skills being taught, but were conscious of the need to scaffold learning. They valued the role of the teacher as an expert more than as a facilitator.

The top statements focus on the continuity of modelling and explaining in the context of a sequence of lessons, building on prior learning through questioning (Q17,+2) and 'signposting' the next steps for learners later in the lesson or in a future lesson (Q14,+2). This group values the use of examples, analogies and similes to illustrate concepts or processes within the lesson (Q11,+2) and were conscious of potential problems, including risks and hazards. Among the higher rated statements this group also valued questioning to encourage learners to speculate (Q22,+1) and recall knowledge (Q20,+1). They also focused on the main points/steps being modelled/explained (Q13,+1) and the use of examples to illustrate these steps/stages (Q25,+1), viewing it as part of a running commentary (Q7,+1). They also saw the importance of monitoring learners understanding when they are applying knowledge/skills that have been taught (Q24,+1).

Among the lower ranked items are the use of questioning to probe knowledge from other subjects (Q19,-1) and making connections with other related concepts/processes (Q8,-1). Also rated lower than other items was the need to address misconceptions (Q16.-1), refer to implications of decisions/actions made during learners application of knowledge/skills (Q10,-1) and providing learners with readily available information about potential problems (Q6,-1). This group were also less focused on the practicalities of preparation in advance (Q26,-1), sharing learning intentions (Q4,-1) and the need for high standards and expectations (Q18,-1). The bottom items were that they should wait for learners to attempt a task that has been modelled/explained before intervening (Q12,-2) and prompting to identify problems for themselves (Q15,-2).

Factor 5: learning as an experience scaffolded by the teacher

Factor 5 is comprised of one biology, one chemistry, one English, one history, one mathematics and one physical education students. This group were focused on scaffolding of learning and were conscious of misconceptions and potential problems. They appear to value the role of the teacher as a facilitator more than as an expert.

The top statements focused on addressing misconceptions (Q16,+2) and learners' engagement with the task before intervening (Q12,+2); although they also valued moving around the room to support learners when they are applying knowledge/skills (Q24,+2). They also valued information about potential problems, including hazards and risk, being made available to learners in the lesson (Q6,+2) and the use of questioning to encourage pupils to speculate (Q22,+2). Among the higher rated statements this group also valued questioning to help learners recall knowledge (Q20,+1), including knowledge from prior lessons (Q17,+1) and other subjects (Q19,+1), preparation (Q26,+1) and prompting learners to identify potential problems, including hazards and risks, for themselves (Q15,+1). The provision of a running commentary was also valued (Q7,+1).

Among the lower ranked items were reference to the application of a concept/process being modelled or explained (Q2,-1) and 'signposting' the next steps (Q14,-1). They were also less focused on preparation of examples (Q23,-1) and the wider overview of the content to be modelled/explained (Q1,-1). The bottom items were referring to implications of decisions/actions made during learners application of knowledge/skills (Q10,-2), as well as sharing learning intentions (Q4,-2) and the need for high standards and expectations (Q18,-2). Having highly ranked making potential problems available to learners in the lesson (Q6,+2) and prompting them to identify problems for themselves (Q15,+1), this group did not prioritise identifying these for the learners (Q3,-2).

Summary of Factors 2 and 5

Factor 2 is being described as 'learning as a continuum led by the teacher' and Factor 5 'learning as an experience scaffolded by the teacher'. Although both have distinctive characteristics, they also share some common ground. Both groups value the use of questioning to help learners to recall and encourage speculation, although Factor 5 values questioning more highly overall. They also share the belief that the teacher should provide a running commentary during modelling/explaining, then move around the room to support learners afterwards. Similarly, both groups are less sensitive to the need to present the learning intentions for a demonstration. They also rank the setting of high standards and expectations or making learners aware of potential implications of decisions or actions they might take when applying knowledge/skill. It should be noted that a lower ranking does not necessarily indicate that a participant does not agree that a particular item is important, but that it is less so than others.

Discussion

There appears to be more commonality between STEM disciplines (n=23) than the wider range of practical subjects (n=41) in their responses to this study (Table 3); where a wider number of factors are comprised of practical specialists than STEM. This finding challenges the hypothesis stated above, that D&T is more closely aligned with the views of preservice teacher of 'practical' than STEM subjects – at least in terms of these preservice teachers views on teacher modelling and explaining at the beginning of their training. A potential factor in this apparent difference, may be due to the high number of mathematics (the only STEM subject not also classified as practical in this study) preservice teachers represented in Factor 2. However, practical subjects represent 50% or more of four factors, as opposed to STEM with two. Therefore, this paper has focused on the two factors where STEM specialists are predominant. Compared with the findings from McLain (2018, 2021) with D&T educators, there appears to be stronger correlation with predominately STEM groups in this study. Also the larger number of participants associate with Factor F2, may indicate a subconscious bias towards behaviourist approaches in these preservice teachers.

The parallels between the two groups focused on in this paper and those from McLain (2021) are suggestive of a hypothesis that there may be two distinct architypes for the teacher in modelling/explaining mode: the more behaviourist 'teacher-expert' and the more constructivist 'teacher-facilitator'. Both groups are conscious of the importance of learning and progress, sharing many similar values. However, the choices on what each group prioritises reveals what they value, or aspire to value – it must be noted that the views expressed by participants may not be reflected in their actions, but rather indicate their subjective position.

The similarity between the two groupings in this study of biology, chemistry, computing, mathematics and physics preservice teachers and the responses of D&T teachers (2017) and teacher educators (2019), opens up opportunities for collaborative ITE provision in STEM. As subjects that utilise teacher modelling and explanation, including demonstration, there may be some benefit in coteaching and collaboration facilitated by STEM teacher educators in this area of pedagogy.

Conclusion

This study suggests that there may be (at least) two strong architypes that many preservice teachers of STEM subjects align themselves to. The fact that previous studies with experienced teachers and teacher educators revealed similar findings, indicates that the conclusions of this study can be asserted with some confidence – despite the novice status of the participants. It is also important to note that this study focused on preservice teachers, early in their ITE, and narrowed down from 7 groupings identified in the analysis to the two where there was the highest proportion of STEM specialists. Having identified two STEM architypes, *expert* and *facilitator*, it may be useful to explore these approaches with preservice STEM teachers as interdisciplinary groups; both to help them reflect on their own aspirations and to challenge them to expand (rather than restrict) their practice in relation to their understanding of education theories. The 26 statements in Table 4 could be used by teacher educators with preservice teachers to promote professional dialogue around teacher modelling and explaining; both as discrete subject groups and in collaboration with peers from the wider suite of STEM disciplines. Future study may benefit from observations of preservice teachers on teaching practice, encouraging dialogue around intent and implementation, between university tutors, school mentors and preservice teachers. Furthermore, this study focuses on the two groupings of respondents (factors F2 and F5 – see Table 3) that most strongly represent STEM preservice teachers. The other five groupings also warrant further analysis, in particular the three (F1, F3 and F4) with strong representation from respondents in 'practical' subjects.

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