

Connecting Mathematics Teaching with Vocational Learning

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Abstract

For many vocational students in England, mathematics is now a compulsory part of their programme, yet the inclusion of an academic subject within a vocational course presents challenges. In this paper, an analysis of a series of case studies of vocational student groups in Further Education colleges in England shows how contrasting practices in ‘functional mathematics’ and vocational classes reinforce perceptions that mathematics is an isolated and irrelevant subject. Some mathematics teachers made contextual connections by embedding mathematical problems in vocationally-related scenarios but distinctive socio-cultural features of vocational learning situations were often absent from mathematics classes. Addressing this disconnection requires a pedagogical approach and classroom culture that links mathematics learning with vocational values. The findings suggest that adopting mathematics classroom practices that reflect the surrounding vocational culture creates greater coherence for students and has positive effects on their engagement with mathematics learning.

Keywords: mathematics, functional mathematics, vocational education

Background to the study

The separation of vocational and academic pathways in post-16 education is a result of long-standing divisions that remain unresolved within the English education system (Young, 1998). Entry to the academic pathway is largely controlled by success in GCSE examinations at age 16 and those with low GCSE grade profiles often transfer to vocational pathways in separate institutions such as Further Education colleges. The divisions between the academic and vocational pathways are not only institutional but there are distinct differences in the curricula, qualification types and forms of knowledge associated with each strand. Students have constrained choices in post-16 education within a highly-stratified system (Pring et al., 2009) that tends to prioritise the academic over the vocational.

Within vocational education, both the mathematical skill levels of students and the qualifications undertaken have attracted criticism (Wolf, 2011). Historically, many low-attaining 16-year-olds have taken no further mathematics qualification by age 18 (DfE, 2014). Recent policy changes, however, now require these students to work towards re-sitting the GCSE mathematics examination until they achieve a grade C. When coupled with the recent extension of compulsory education to age 18 years in England, this means that many more students on vocational pathways now learn mathematics as a compulsory part of their study

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programme. This GCSE mathematics curriculum is traditional and academic in nature and so does not sit easily with their vocational learning.

The research reported herein was conducted prior to these national policy changes, with students who were taking a Functional Mathematics qualification rather than re-sitting the GCSE examination. Functional Mathematics focuses on problem solving and applications in ‘real life’ scenarios and, for most students in the study, the subject was compulsory due to college policies, although it was not a government requirement at the time. This paper examines the contrasts between mathematics teaching and vocational learning that emerged from a wider study of the students’ learning experiences of mathematics and was primarily concerned with students aged 16-18 years. Before examining the research findings, some of the relevant historical academic-vocational tensions are discussed.

Divisions of knowledge, curriculum and pedagogy

The institutional divisions within the English education system can be traced back to the separate establishment of schools, work-related training and adult education. These educational traditions have continued without a coherent overarching policy for education as a whole (Maclare, 1991; Young, 1998). The academic and vocational education traditions that have grown from these roots have different purposes, curricula and qualifications but also reflect longstanding societal hierarchies (Hyland, 1999). The “links between the stratification of knowledge in the curriculum and patterns of social inequality and distribution of power in the wider society” (Young & Spours, 1998, p. 51) are evidenced in the privileging of academic over vocational pathways.

Low-achieving students often undertake vocational qualifications after the age of 16 although these qualifications are seldom considered in schools (Hodgson & Spours, 2008) where the focus remains on academic GCSEs, both prior to age 16 and after the parting of the academic-vocational ways. Vocational training in Further Education colleges has the twin goals of developing practical competencies and acquiring relevant technical knowledge in order to prepare individuals for employment. In contrast, academic qualifications in post-16 pathways prepare students for higher education and GCSE mathematics continues to act as a highly-valued ‘gate-keeper’. Despite some attempts to bridge the divide by increasing the academic rigour of vocational qualifications or bringing vocational education into schools, these initiatives have historically had limited success (Hyland, 1999).

The teaching of academic and vocational subjects draws upon contrasting traditions (Lucas, 2004). For vocational education one of the major influences has been the close association with the apprenticeship model of learning, in which the teacher, as an occupational expert, demonstrates skills for students to replicate until they achieve competence in a ‘community of practice’ (Lave & Wenger, 1991; Wenger, 1999). Teachers may take a range of roles within vocational workshops and classrooms but practical activity is particularly important in a learning process that is essentially social and collective (Unwin, 2009); the emphasis is on developing competency within a community rather than acquiring knowledge (Hyland, 1999).

The academic strand within Further Education reflects a more classical, liberal approach to education in contrast to the practical usefulness valued by vocational areas. Robson (2006) argues that pedagogy needs to reflect the disciplinary context but this causes an uneasy relationship when a subject such as mathematics is taught as part of a vocational programme. Learning mathematics for vocational purposes focuses activity on a particular context and practical need but this utilitarian view (Ernest, 2004) is in tension with the broader appreciation of mathematics and abstract knowledge valued in academic pathways.

Vocational departments in Further Education colleges associate strongly with their particular occupational values (Robson, 1998). The tendency for students to adopt these values (Colley, James, Diment, & Tedder, 2003) suggests that students primarily focus on their vocational goals, resulting in perceptions that subjects with no clear vocational purpose are peripheral.

Such values are key components of departmental culture but are also important influences in the teaching of mathematics (Bishop, 2001; FitzSimons, 1999). Against this background of historical traditions, our interest here is in the differences between students' experiences of mathematics and vocational learning, including the pedagogies and values enacted in these lessons.

Research questions and methods

The research questions of interest in this paper are:

- In what ways are students' experiences of learning in vocational sessions and Functional Mathematics classrooms related?
- How does this affect their learning of mathematics?

To answer these questions we compare teaching and learning approaches in mathematics and vocational sessions, using lesson observation data from a wider study of vocational students' experience of functional mathematics in Further Education.

The research involved a series of nested case studies within vocational areas in three Further Education colleges, from which cross-case and within-case comparisons could be made. Seventeen different student groups were involved from the vocational areas of Construction, Hair and Beauty, and Public Services and each student group formed a separate case study. The research was exploratory as well as explanatory and used multiple methods, both qualitative and quantitative, to provide triangulation between sources and methods. Drawing on ideas involved in grounded theory, an iterative process of analysis was used that involved the coding of qualitative data and constant comparison to identify emerging themes.

In addition to the lesson observations of the same student groups in Functional Mathematics and vocational sessions, data was obtained from student focus group discussions, interviews with Functional Mathematics teachers, interviews with vocational teachers, staff questionnaires and individual student card-sorting activities. In the card-sorting activities students either ranked statements, or placed statements on a Likert scale, to describe their experiences of school and college. In the following section we present some of the relevant results from these activities as background before examining the lesson observation data.

Research findings

When students ranked statements about their reasons for coming to college, the dominant reasons that emerged from the analysis were 'I was interested in the course' and 'I wanted to improve my education'. Focus group discussions provided further evidence that most students were interested in their vocational courses and valued the opportunity to choose the direction of their education, even though these choices were somewhat constrained by their GCSE profiles.

Secondly, students placed statements regarding their experiences of college on a Likert scale and discussed these in focus groups. Most students depicted college in positive terms (See Table 1 in Appendix I) referring to features such as being treated in a more adult manner, experiencing greater freedom, having more agency and taking more responsibility for their own learning. These results suggest that values relating to adulthood and employment were important to students and welcomed their presence in the college culture. In contrast, many students referred to their experiences of mathematics in school in negative terms (Table 2). Focus group discussions provided further evidence that most students approached college with a view that mathematics was a remote and irrelevant academic subject, one associated with previous failure and disaffection.

Within this context, where many students were positive about their general experience of college but showed an initial negative disposition towards mathematics, we compare their experiences in vocational and mathematics sessions. The differences will be set out using two short summaries of observed sessions. These exemplify the high contrast between vocational sessions and the traditional features of mathematics lessons that were evident in many of the seventeen case studies. After summarising the key features, the approaches used by some functional mathematics teachers to connect the two learning situations will be considered.

Observation A: Beauty Therapy students in the training salon

The students were giving facial treatments to clients. This involved individual skin consultations and one-to-one practical work. One student, Nina, was demonstrating the treatments on a “doll” (artificial head) to students who had missed the previous session. Nina explained the stages of the facial and how each had to be completed properly but within a timescale of about 30 minutes since extra time would lose money for the business. Another student, Gemma, was acting as the salon manager: replenishing products, keeping records of the treatment times and generally making sure the salon was running smoothly. Quiet, relaxing music was playing as each student worked individually on their client. Several times during the session the students were reminded by the teacher to talk solely to their client and not chat to other students. All the students were wearing clean uniforms and seemed to have taken considerable care over their personal appearance. Students were expected to maintain their own uniforms, have their hair tied back and keep jewelry to a minimum. Apart from moderating the atmosphere, the vocational teacher watched and advised, acting as a guide and source of further information when necessary.

Observation B: Functional mathematics with Public Services students

The session took place away from the Public Services vocational area. Space was tight and although the students could all be seated at tables there was little room for the teacher, David, to move between them. This had an impact on the lesson since it was difficult for him to check work, give feedback and support individual students. After a formal teacher-centred introduction and some worked examples on the board, the main activity was to complete a series of worksheets about areas and perimeters. These were given out one at a time so that the completion of any worksheet was quickly followed by the provision of another. David tried to circulate to mark work and encourage students to participate but it was difficult to get students to engage with the work and frequent reminders were needed to keep them on task. He worked hard to keep distractions under control by reminding students to be quiet and get on with their work. These attempts to impose a working environment dominated the session and, despite being calm and persuasive, David’s strategy seemed largely ineffective. Towards the end of the lesson students who had completed the work were allowed to go early whilst the others were retained and urged to continue until the official end of the lesson.

In the vocational session students were expected to adopt professional standards of behaviour and take significant responsibilities such as making decisions about treatments, supervising other students and providing customer care. In contrast, the Functional Mathematics lesson was a tightly structured, teacher-controlled session, closely resembling a typical school mathematics classroom. Students had little opportunity to make decisions about the learning process or take responsibility for their own progress as the whole process was largely controlled by the teacher.

Within the training salon there were clear rules regarding personal appearance and professional conduct but there was also considerable freedom. Students were expected to focus on their client during the session but walking around to collect equipment or products was part of the normal routine. Unprofessional chatter with their peers was prohibited but consulting with other students for support or advice was an accepted feature of working practice. In the functional mathematics classroom, space was constrained and students were expected to remain seated throughout the session. This created a very different environment and influenced the way in which learning took place.

David's approach to teaching was topic-based and the lesson involved an explanation of the mathematical content before demonstrating the processes through worked examples on the board. This was followed by student work on further examples that they were expected to complete quietly and independently. For David, mathematics should be learned in an organised, orderly classroom with clear rules enforced by the teacher. In contrast, the teacher's role in the salon was mainly to observe and advise. Students learned from one other as well as from their teacher in this collaborative and supportive environment.

There were further contrasts in the type of tasks used. In the vocational session practical skills and theory were integrated into tasks. For example, relevant theory about skin types needed to be recalled and used during consultations with clients. Tasks in the salon would generally take some time to complete and there was some flexibility about the time taken for each component as long as the overall treatment was completed within a reasonable timescale. Learning in David's classroom mainly involved short written tasks with the expectation that students would remain 'on task' and completion would be followed immediately by additional written work.

These two approaches to teaching and learning seemed to be based on contrasting values and assumptions regarding the role of the teacher, the environment and the processes that would be most effective for learning. Relationships between the teachers and students in these two examples were very different, as were the social structures and classroom cultures in which roles and relationships were embedded. Comparisons with other observations of vocational sessions in salons, workshops and classrooms, showed that this session was very typical. This cross-case analysis led to the identification of four main areas in which there were common characteristics:

- *Responsibility, agency and freedom.* Students worked within loose frameworks of rules that related to health and safety requirements or professional standards but had freedom to make individual decisions. They were expected to take responsibility for their learning and were placed in positions of responsibility for clients or other students. There was freedom of movement around the vocational salons, workshops and classrooms.
- *Vocationally-related values and expectations.* Adult and work-related values, dispositions and behaviours were encouraged and evident in most sessions.
- *Student-focused learning through guided activity.* Learning processes centred on developing practical competencies through replication of skills demonstrated by respected vocational experts. Their role was to facilitate learning, with students acting as apprentices in a community where informal peer learning was often evident.
- *Integration of knowledge and skills into substantial tasks.* Practical skills were highly valued but knowledge from theory sessions was often intertwined into tasks. Tasks were usually substantial with multiple elements and time-scales stretching over days or weeks. Students worked at their own pace, making individual decisions about the order of the sub-elements and the methods to use.

These four areas contrasted with the formal, traditional approach to teaching mathematics in David's lesson where the following key features were identified:

- *Teacher authority and control.* The rules in the classroom reflected the values and priorities of the teacher-authority who expected students to comply. The teacher directed and controlled the learning process. Students had little agency in their work. They were expected to remain seated throughout the session, to work quietly, individually and follow directions.
- *Academic values and expectations.* The students were learning a subject as a series of disconnected topics, through a process of knowledge transfer rather than developing a set of skills.

- *Teacher-led activity.* The lesson was planned and closely directed by the teacher. Mathematical knowledge was delivered to students who did not aspire to be mathematicians and had little sense of how this learning might be useful.
- *A focus on written work.* There was a reliance on worksheets and written solutions to questions. The tasks were usually short and students were expected to remain ‘on task’ throughout the lesson.

Not all of the mathematics lessons were, however, like David’s. We now consider those cases in which the Functional Mathematics teachers adapted to the vocational environment with lessons that were better connected to the students’ vocational learning experience. The key features of these lessons are, again, presented using a short lesson observation as an exemplar, followed by a summary of the common characteristics of similar lessons from the cross-case analysis.

Observation C: Functional mathematics with Hairdressing students

The session took place in a separate building, some distance from the main Hairdressing area. As the students arrived the teacher, Richard, greeted them individually and engaged in relaxed conversations about what they had been doing both inside and outside college since the last class. His introduction to the lesson involved a class discussion about using units of time. Students readily talked about their difficulties, both asking and responding to questions until they were satisfied that they understood the concepts and processes involved. The main task in the lesson was to draw up an appointment schedule for a hair salon from a list of requests for appointments involving different hair treatments. This required students to use vocational knowledge about the time needed for each treatment and considerations about appropriate business decisions, in conjunction with mathematics. The students produced individual schedules, using different methods and formats, but discussed their strategies and decisions freely with each other. The teacher supported and guided by asking students individually about their methods, assumptions and decisions. Finally, the teacher checked their progress with a longer-term integrated homework assignment in which students were using vocational knowledge, English and mathematics to produce a business plan for a new hairdressing salon.

Although the physical separation of the mathematics classroom from the students’ vocational base was similar to the situation of the Public Services lesson, the key pedagogical features contrasted with those observed in David’s lesson and were more closely aligned to the vocational session. Similar features were evidenced in a number of Functional Mathematics sessions and the cross-case analysis suggested the following key features of a more ‘connected’ functional mathematics classroom:

1. Teachers adopted pedagogies that made connections through context, classroom discourse and programme synchronization:
 - Using vocational situations as the context for mathematical problems. This was effective when the details of these scenarios were accurate and resembled situations that students had actually experienced;
 - Encouraging an integrated discourse about mathematics in students’ lives by using informal conversations and interests as a basis for improvising discussions about applications of mathematics;
 - Synchronizing the Functional Mathematics scheme of work with the vocational programme to increase perceptions of relevance.
2. Teachers developed classroom cultures that were more in keeping with values of the surrounding vocational culture by:
 - Creating flatter social structures than those in traditional school mathematics classrooms;
 - Adopting a supportive, facilitating role;

- Developing equitable relationships with students;
- Using peer learning as a key learning strategy.

In cases where these features were present, our cross-case analysis suggested that students responded more positively to learning mathematics than in classrooms where the pedagogy and culture were more traditional. These features seemed to reduce the sense of disconnection between the mathematics classroom and the vocational programme and as a result their engagement with mathematics improved.

Discussion

For many of the students in this study, learning mathematics was perceived as separate from their vocational learning. However, when learning mathematics was connected to students' vocational development, values and culture then the subject generally became more relevant, meaningful and coherent. Although students retained a narrow focus on their vocational area (Hodgson & Spours, 2008) and only identified a limited utilitarian purpose for mathematics (Ernest, 2004), their acceptance of Functional Mathematics as a vocationally-relevant subject represented a shift in perspective that had a positive effect on their engagement with mathematics.

The students in this study were in a transition from school education to the workplace and were experiencing the tensions between formal, abstract academic learning and the development of vocational skills to achieve professional competence. As FitzSimons (1999) explains, mathematics in the workplace becomes a tool, in contrast to being the object of activity in mathematics classrooms. The transition from school to the workplace therefore involves changing students' perceptions of mathematics from object to tool, but this is a gradual process and not straightforward. In the interim period of being a 'trainee' in college students are caught between these two positions.

The mathematics learning of vocational students is situated in a complex socio-cultural environment, influenced by contrasting educational and vocational values and traditions. Although historical, social and cultural influences affect values generally in mathematics classrooms (Bishop et al., 1999), the co-existence of Functional Mathematics lessons within vocational programmes require students to change between cultures with typically dissonant values, unless cultural divisions can be bridged and values harmonized. In practice, students tend to adopt the values of their vocational area, as indicated by previous research (Colley et al., 2003) and the alternative value system, that frames much mathematics teaching, generates tensions. Some reconciliation of these different cultures is necessary to enable students to see learning mathematics as an integral and meaningful component of their vocational training.

Values relating to employment and adulthood were dominant in the general college culture and were also important to students. In some cases Functional Mathematics teachers created social structures that facilitated a more open and equitable classroom culture and this was better aligned to these values. Others embraced specific vocational values, such as teamwork for Public Services, in their teaching approaches. These adjustments to classroom culture provided a more coherent learning experience and helped stimulate student engagement.

In the observed vocational sessions, the role of the teacher was one of an occupational expert in a learning community similar to a 'community of practice' (Lave & Wenger, 1991; Wenger, 1999). In this social arrangement students were learning from the teacher's expertise and from one other by developing practical competencies coupled with technical knowledge. Functional Mathematics lessons involved a different learning process as students were neither aspiring to be mathematicians nor intending to be teachers of mathematics and therefore a 'community of practice' model was inappropriate.

The analysis suggests that the practices of a *connected* mathematics classroom in colleges can enable students to bridge some of these divisions by presenting mathematics as a subject that

is not confined to the domain of academic knowledge but can also constitute vocationally-related skills. The pedagogy of the *connected* classroom in this study reflects some of the principles of embedding from previous research (Eldred, 2005; Roberts et al., 2005) but it also highlights the importance of shared values and compatible cultures in mathematics classrooms for vocational students. Bridges between different practices, of vocational learning and mathematics teaching, were constructed using key points in these separate discourses to make connections (Evans, 1999). These connections enabled a form of 'boundary crossing' that reconciled some of the conflicts for students between their vocational training and their learning of mathematics. Although the learning processes for mathematics and vocational skills retains some fundamental differences, these approaches suggest ways in which greater coherence and better engagement can be brought into the student experience of learning mathematics in vocational education.

Conclusions

The academic-vocational divisions and tensions of the English education system were evident in the student experience through contrasts in the pedagogy and purpose of learning in vocational and mathematics sessions but there were also important differences in the social structures, culture and values within the two separate learning environments. For students in transition from school to the workplace, the vocational training phase is characterised by changing values and shifting perspectives as students become more orientated towards employment. Bridging the divisions and providing a coherent, meaningful experience of mathematics learning for vocational students requires an understanding of this transition, a non-traditional approach to mathematics teaching and a classroom culture that reflects the values of the surrounding environment that are important to students. The effects of these features within the classroom were significant for students in the study and suggest aspects of teaching in a vocational environment that need to be considered seriously alongside general and subject-specific pedagogy.

In the light of recent policy changes in England it seems that the move towards the more knowledge-based, academic GCSE mathematics qualification rather than a 'functional' curriculum is likely to create a greater distance between mathematics and vocational learning for students. Further research is needed to ascertain the actual effects of these policy changes on the dispositions and attainment of students who are required to re-sit GCSE mathematics courses but there are clear indications in this study that addressing the cultural divisions between mathematics and vocational learning is an important factor in creating a meaningful and successful experience for students. These findings have implications for the training of mathematics teachers for Further Education. They also raise questions for policy-makers for whom the achievement of an academic minimum standard in mathematics is privileged over engaging students in a meaningful experience that prepares them for the workplace.

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Appendix I

Table 1.
Student Views on What College is Like

QUESTION B: What is college like? (compared to school)					
STATEMENT	SA	A	N	D	SD
There is more freedom than there is in school	45	42	9	6	1
It has been easy to make friends	32	48	23	0	0
I get on with the staff in college	25	58	16	4	0
You are treated better at college than school	26	50	21	6	0
College work is easier than school	8	32	38	21	4
The staff treat you like adults	23	51	15	10	2
My course is interesting	47	44	8	2	1
I like the subjects I do	32	57	10	4	0

Table 2.
Student Experiences of Mathematics in School

QUESTION D: When you did Math at school how did you feel?					
STATEMENT	AA	S	H	O	AN
I worked hard	13	34	31	14	9
It was difficult	9	29	28	28	8
I got distracted	22	31	16	29	4
I liked Math	9	20	14	20	38
I felt stressed	15	20	19	29	19
I was bored	21	20	26	27	7
I liked the teacher	11	23	19	13	36
I felt confident	4	22	21	38	17
It was interesting	2	14	18	34	34
I understood it	6	30	27	24	15
It was confusing	14	21	23	38	6
I could have done better	34	30	17	19	0