Numeracy for adults

Latest findings from teaching and learning research

Literacy, language and numeracy research

Numeracy for adults

1 OVERVIEW

1.1 Structure of the review

The critical factors for effectively embedding numeracy are described in three sets of research-based understandings as follows:

- How adults develop their numeracy expertise.

- The features of effective embedded numeracy provision.

- Managing and sustaining change to achieve effective long-term embedding of numeracy.

Each of these three sets is developed as four understandings.

The first section of the review provides an overview of each of the three sets of understandings. The detail of these understandings is then provided in the following sections, in a format that describes the research base for each understanding, outlines the implications for practice and identifies key references in the area.

1.2 How adults develop their numeracy expertise

Adults engage in learning for their own larger purposes. These purposes are associated with their roles in society as workers, family members and community members.

- Learning programmes that are transparent allow adults to see how their learning links to their own particular purposes.

- Adults need to be involved in setting learning goals and monitoring their progress towards these. Learning is a purposeful goal-directed activity. An ongoing goal-setting process is integral to effective learning.

- Motivation is a key factor in engagement and achievement. Learners are motivated when they can see the value of learning for their own goals.

Adult learners develop expertise by building on their existing knowledge, skills and experiences.

- A constructivist approach to teaching and learning focuses on the development of learners' conceptual understandings through meaningful learning experiences.

- Teaching approaches that are based on constructivist theory build on learners' existing knowledge, experiences and understandings, and support individuals to actively construct meaning for themselves.

- As learners develop expertise in a field, they become increasingly aware of the key concepts that help to structure their knowledge and they develop meta-cognitive strategies that allow them to monitor their own learning.

- To successfully employ a constructivist approach, tutors require a sound conceptual basis of mathematics.

Adult learners develop their numeracy most effectively in contexts that have meaning to them. As learners develop their expertise, their increasing awareness of their knowledge and skills allows them to apply them in a wide range of contexts.

- Thinking and learning depend greatly on the social and cultural contexts in which they occur.

- Learning can be transferred from instructional contexts to work or other everyday situations. Transfer is enabled where learners are aware of the underlying principles behind content, where they are engaged in mathematics and where they are supported to articulate their own problem-solving approaches.

- Learning is enhanced through interaction with more knowledgeable individuals that can scaffold developing understandings.

Mathematics anxiety is experienced by many adults. This makes it difficult for them to access their working memory and think logically, and results in lower course completion rates.

- Where teaching approaches focus exclusively on correct answers and give little cognitive support, learners who experience repeated failure may develop negative perceptions of their own mathematical ability which contribute to the development of mathematics anxiety.

- Mathematics anxiety decreases the efficiency of the working memory and makes it difficult for individuals to think logically.

- Teachers who model positive attitudes towards mathematics, and instruction focused on relevant content in meaningful contexts have been found to positively influence the attitudes of anxious learners.

1.3   The features of effective embedded numeracy provision

Where tutors work as a team, learners are more likely to stay in training and complete vocational qualifications.

- Successful team approaches may involve tutors in joint planning, observation and team teaching as appropriate. Regardless of the approach used, tutors require sufficient time to be allocated to enable them to work together.

- Team approaches are supported where numeracy and vocational tutors have opportunities to learn from each other.

- Effective teaching teams in adult education are learner focused and share responsibility for learner progress.

Successful approaches to embedding numeracy clearly link literacy, language and numeracy (LLN) and vocational components of the course.

- Links between LLN learning and vocational learning are clearly and explicitly identified.

- LLN instruction is provided as it is required for the vocational task at hand.

- Teaching and learning materials reflect use of numeracy within the vocation and are differentiated for learners' varying numeracy needs.

Effective assessment in programmes where numeracy is embedded makes use of learning progressions to provide direction for teaching programmes and to monitor progress toward learning goals.

- Learning continuums clearly describe the growth of knowledge and skills that occurs as learners develop their expertise in a particular area.

- Diagnostic and formative assessment which maps student progress against learning progressions provides valuable direction for teaching programmes.

- Successful assessment procedures provide both formal and informal feedback to learners about their progress.

- There is a need to develop appropriate assessment instruments for use in adult numeracy education.

Embedded numeracy provision is facilitated by appropriate organisational policies, management structures, resourcing, and working conditions.

- Institutions that adopt a whole-organisation approach to the development and support of embedded programmes are more likely to be effective.

- It is important for administrative procedures and the allocation of practical resources to reflect the importance of both numeracy and vocational learning.

1.4 Managing and sustaining change to achieve effective long-term embedding of numeracy

Organisations are more likely to develop and maintain effective approaches to embedding numeracy when the value of LLN is understood and numeracy is viewed as an integral part of vocational training.

- Approaches are more likely to be sustained where managers understand that embedded numeracy is effective in increasing participation and raising achievement.

- Numeracy teaching is more likely to be effective where it is regarded as an integral part of vocational training.

- Tutors and employers play a key role in communicating the value of numeracy skills to learners.

Teaching materials are important tools that can substantially influence the content and enactment of instruction.

- Teaching materials are tools used by tutors as they design instructional programmes. The ways in which tutors use teaching materials are dependent upon their own understandings, the understandings and characteristics of the students they teach, and the contexts of instruction.

- Because teaching materials directly influence the process of teaching, they have been widely used as a tool in instructional reform.

- Teaching materials need to be developed in ways that clearly anticipate the role of the tutor in implementation, and include important information that enables tutors to make decisions about how and when to use the material presented.

Professional development programmes can be effective in improving tutor practice and learner performance.

- Effective professional development programmes focus directly on the link between learning and tutor practice.

- Effective professional development programmes support tutors to identify and examine their current understandings and approaches as they develop their professional knowledge base.

- Ongoing professional development programmes support tutors to take responsibility for student learning and this provides a sound basis for continual improvements to knowledge and practice.

Assessment data provides valuable information that can be used systematically to improve programmes.

- Continuous programme improvement requires organisations to clearly specify learning goals, systematically monitor the progress of all learners towards these goals and then revise teaching programmes on the basis of this information.

- Individual and aggregate measures of achievement enable organisations to focus on improving the performance of both individual learners and the organisation as a whole.

- Professional learning communities can successfully effect and sustain change by highlighting student performance.

2 HOW ADULTS DEVELOP THEIR NUMERACY EXPERTISE

> Adults engage in learning for their own larger purposes. These purposes are associated with their roles in society as workers, family members and community members.

Research findings

Children attend school because of legal mandates and strong social and cultural forces that view school as the "work of childhood" (Comings et al. 2000, p. 1). In contrast, adults generally make an active choice to participate in educational programmes and they do so in order to achieve broader purposes in their lives.

We undertake cognitive tasks not merely as an end in themselves but as a means of achieving larger objectives and goals that have meaning in the community (Scribner, 1988).

Adults seek to develop their LLN skills in order to gain access to information, give voice to their opinions and ideas, take action to solve problems and create future opportunities in the form of further qualifications. Achieving the purposes they set for themselves enables adults to more effectively fulfil their roles in society as workers, family members and community members.

Adults are more likely to engage in learning programmes for sustained periods and achieve success when it is clear to them how their learning is linked to their own particular purposes. Transparent learning programmes acknowledge and support learners' purposes by helping them to establish specific learning goals in line with these. In addition, where learners are involved in monitoring their progress towards learning goals, they are more likely to persist and achieve success in learning programmes.

Motivation is a key factor in engagement and achievement. Learners are motivated when they can see the value of learning for their own goals. Adults are more likely to be motivated to engage with LLN learning when it is embedded within a vocational or leisure course which is their primary motivation.

Implications for practice

Adult learners are more likely to be engaged and achieve success when:

- learning programmes clearly articulate course content and outcomes to enable adults to be clear about how the learning links with their own particular purposes

- course information is clear, unambiguous and accessible. Specific examples of content can be useful in communicating with potential learners

- adult learners are involved in setting learning goals and monitoring their progress towards these

- learning activities incorporate clearly specified outcomes.

Embedding LLN learning within vocational courses will increase adults' motivation for developing their knowledge and skills in LLN.

References: Bingman & Stein (2001); Coben (2003); Comings, et al. (2000); Gillespie (2002b); Roberts et al. (2005); Scribner (1988); Swain et al. (2005).

> Adult learners develop expertise by building on their existing knowledge, skills and experiences.

Research findings

A constructivist approach to teaching and learning focuses on supporting learners to develop conceptual understandings through meaningful learning experiences. This is in contrast to a behaviourist approach, where skills and knowledge are developed through reinforcement.

Teaching approaches that are based on constructivist theory build on learners' existing knowledge. Learners actively construct knowledge as they make sense of new information and experiences by extending or changing their current ideas and understandings. Within this approach, the role of the tutor is to support individuals to actively construct meaning for themselves.

> "...taking a constructivist approach to building knowledge and skills focuses on helping students develop their understanding and make sense of the world." (Bingman & Stein, 2001, p. 19)

Instruction is aimed at developing a "richly structured knowledge base" (Gillespie, 2002c, p. 2) rather than acquiring a selection of isolated facts or mastering a number of operational procedures. The connections between areas of learning are valued and emphasis is given to the ways in which different areas of content are related. Teaching is structured around key concepts and big picture ideas.

As learners develop expertise in a field, they become increasingly aware of the key concepts that help to structure their knowledge. As with experts in the field, these key ideas give structure to their developing knowledge and enable them to discern and remember significant new information. In addition, learners can be supported to develop meta-cognitive strategies similar to those used by experts to monitor and control their own thinking processes. Assisting learners to develop and measure their success by reflecting on what they have learnt helps them to take responsibility for their learning and develop independent learning and study skills.

To successfully employ a constructivist approach, tutors require a sound conceptual understanding of their subject area and an appreciation of the ways in which different aspects of learning within their area are related. Effective teachers of mathematics possess deep conceptual knowledge which is based on the ability to reason rather than simply apply rules for operating.

Implications for practice

A constructivist approach to teaching and learning has been shown to support learners to develop conceptual understandings. Constructivist approaches:

- acknowledge and value learners' existing knowledge by supporting learners to identify their current understandings and investigate these in the process of developing new ideas

- are focused on the development of conceptual understandings rather than the memorisation of facts and procedures for operating

- develop reflective thinking and reasoning

- utilise teaching and learning activities that are relevant and meaningful to learners

- articulate the key ideas within a field and organise learning around these

- make explicit links between areas of learning within a field

- support students to reflect on their own learning in order to gain increased control over their own thinking processes and develop independent study skills

- promote the development of conceptual knowledge among tutors.

References: Askew et al. (1997); Bingman & Stein (2001); Cobb (1994); Coben (2003); Fosnot (1996); Gillespie (2002c); Ma (1999); Piaget (1978); Swain et al. (2005); von Glasersfeld (1995).

Adult learners develop their literacy and numeracy most effectively in contexts that have meaning to them. As learners develop their expertise, their increasing awareness of their knowledge and skills allows them to apply them in a wider range of contexts.

Research findings

A large body of literature has demonstrated that adults' thinking is influenced by the social and cultural contexts in which it occurs. Research examining the mathematics processes of adults working in a wide variety of fields has found that adults have significant control over the problem-solving processes in their everyday lives, calculating mentally with the original context in mind. This is in contrast to students working in traditional school mathematics programmes, where problems are usually defined by the teacher, there is often one preferred method, and numbers are extracted from problems, operated on and then interpreted back into context.

The issue of the extent to which numeracy skills are transferable from one context to another is central to adult numeracy education. Some researchers emphasise the situated nature of cognition and learning and consider all knowledge to be inextricably linked to the context in which it occurs. Within this approach, the transfer of learning into contexts that differ from the instructional context is highly problematic. An alternative body of work asserts that learning can be applied to new contexts, in a process called translation. Within this view, the role of the tutor is to teach in such a way that learners are able to apply what they have learnt to a variety of new situations.

> "The question of the ways in which knowledge, skills and understanding are situated and embedded in contexts and whether or not they are transferable (or translatable) is a key one for all mathematics educators. It is particularly acute for adult numeracy educators because of the expectation that 'numeracy' should be usable…in adult life." (Coben, 2003, p. 53)

Several factors have been found to influence the transfer of learning from instructional contexts to work or other everyday situations. Learning is more easily transferred where learners are aware of the "underlying principles, patterns and relationships" (Gillespie, 2002a, p. 1) within content; where instruction is linked to larger ideas that can be translated across contexts learners are more likely to make this translation. Learners are also more likely to gain transferrable knowledge when the instruction is meaningful. Instruction is meaningful for learners when it is engaging, not necessarily when it is realistic in the sense that it mirrors an authentic everyday situation. In addition, approaches that acknowledge students' own problem-solving methods and encourage them to articulate these have also been found to enable transfer.

Learning is enhanced by social interaction. Vygotsky, and other researchers working in the socio-cultural tradition, highlight the importance of social interaction in teaching and learning programmes. These researchers outline how learning is enhanced through interaction with more knowledgeable individuals that can scaffold developing understandings. Where adults work collaboratively to develop knowledge and skills in a social context, a learning community is developed within the classroom and new understandings are "generated from disjunctions, conflicts and contradictions that occur in the course of people being involved in activity" (Coben, 2003, p. 41).

Implications for practice

Learners will develop numeracy skills and are most likely to transfer their learning to new contexts where teaching and learning programmes:

- clearly convey the key principles and larger ideas within the subject area

- engage learners in meaningful mathematics contexts

- support students to articulate their own problem-solving approaches.

Learning is enhanced where learners are part of a collaborative learning community and are given opportunities to:

- be supported by more knowledgeable individuals

- support each other's learning by giving and receiving assistance and advice

- engage in group work.

References: Bingman & Stein (2001); Bruner (1985); Carraher & Schliemann (2002); Cobb (1994); Coben (2003); Evans (2000); Gillespie (2002a); Lave (1988); Saxe (1988); Swain et al. (2005); Vygotsky (1987).

Many adults experience mathematics anxiety. This makes it difficult for them to access their working memory and think logically and results in lower course completion rates and limited career opportunities.

Research findings

Mathematics as a subject is perceived by many people as abstract and lacking in relevance. Where teaching approaches focus exclusively on correct answers and provide little cognitive support, learners that experience repeated failure may develop negative perceptions of their own mathematical ability which contribute to the development of mathematics anxiety. Although mathematics anxiety generally develops in childhood, its effects are still felt in adulthood and it is widespread throughout the population.

> "Math anxiety is a bona fide anxiety reaction, a phobia with both immediate cognitive and long-term educational implications." (Ashcraft, 2002, p. 184)

Mathematics anxiety decreases the efficiency of an individual's working memory as intrusive thoughts and worries take the focus away from the mathematics task at hand. This makes it difficult for individuals to think logically and results in increased errors and longer processing times when solving problems mentally. In the longer term, mathematics anxiety leads to decreased competence and reduced course completion rates, which may restrict the career options available to adults.

Teachers that model positive attitudes towards mathematics have been found to positively influence the attitudes of anxious learners and mitigate the effects of mathematics anxiety on learning. Where learning programmes are focused on relevant content in meaningful contexts and learners are involved in open-ended activities with extended opportunities for problem solving and discussion, anxiety is also reduced.

Adult learners that aspire to a particular job or career experience a socialisation process as they train for that position. Where LLN skills are integral to vocational training, learners accept these as part of their new professional identity, leading to increased motivation and confidence for learning LLN and decreased mathematics anxiety.

Implications for practice

Adult numeracy educators need to be aware that mathematics anxiety will be affecting the learning of some course participants.

The effects of mathematics anxiety on learning can be mitigated by:

- tutors that model positive attitudes towards mathematics

- instructional programmes focused on relevant content in meaningful contexts

- teaching and learning programmes that provide learners with extended opportunities for problem solving and discussion

- vocational programmes that include LLN skills as an integral part of vocational training.

References: Ashcraft (2002); Ashcraft & Kirk (2001); Coben (2003); Evans (2000); Roberts et al. (2005); Swain et al. 2005); Torgerson et al. (2004).

3 THE FEATURES OF EFFECTIVE EMBEDDED NUMERACY PROVISION

> Where tutors work as a team, learners are more likely to stay in training and complete vocational qualifications.

Research findings

"Successful teacher teams are strongly motivated to provide embedded provision; they have time to plan and work together, and are willing to learn from each other." (NRDC, 2006)

The implementation of a team approach by vocational, numeracy and learning support tutors is strongly linked to the effectiveness of embedded numeracy approaches. However, the ways in which tutors operate as a team vary according to their knowledge, skills and the constraints of the vocational course in which they work. Effective approaches in adult education may involve tutors working collaboratively by planning together, sharing teaching time and space, team-teaching or observing each other at work with learners. As the relationship between vocational and numeracy learning is dynamic, tutors need to be able to work together flexibly and recognise the changing priorities at any one time during the vocational training. Regardless of the approach taken, common to all successful team approaches is the need for vocational, numeracy and learning support tutors to have sufficient time allocated to work together.

Team approaches are supported where numeracy and vocational tutors have opportunities to learn from each other. Studies investigating embedded approaches emphasise the "importance of teamwork, underpinned by a level of understanding, on the part of both LLN and vocational teachers, of one another's work" (Casey et al., 2006, p. 31). In particular, numeracy tutors need to understand how numeracy is used both in the classroom and in the workplace that learners are training for. Conversely, vocational tutors require an understanding of the importance of numeracy, and an ability to adapt vocational content and teaching approaches to reflect the key numeracy concepts involved in each.

Effective teaching teams in adult education are learner focused and share responsibility for learner progress. In practice this means that tutors share vocational objectives for learners and regularly discuss learner progress using shared achievement information.

Implications for practice

Vocational programmes are more likely to effectively embed numeracy learning where tutors work as a team. Effective team approaches are those in which:

- vocational, numeracy and learning support tutors have time allocated to work together

- the model of delivery incorporates teamwork in a way that is appropriate for the tutors, students and vocational objectives of the course which they deliver

- joint planning, team-teaching and opportunities for tutors to observe each other teaching are used flexibly within teaching and learning programmes

- vocational and numeracy tutors have opportunities to learn from each other and gain an understanding of each other's areas

- tutors discuss learner progress using shared achievement information.

References: Bates (2005); Casey et al. (2006); Cranmer et al.(2004); NRDC (2006); Roberts et al. (2005); Swain et al. (2005).

> Successful approaches to embedding numeracy clearly link LLN and vocational components of the course.

Research findings

Approaches to embedding numeracy are more likely to be successful where the links between numeracy and vocational learning are clearly and explicitly identified. In particular, both vocational and numeracy tutors need to understand the ways in which numeracy is used in vocational tasks and the numeracy requirements of the learning environment.

Research into effective embedded numeracy approaches emphasises the importance of the relative timing of numeracy and vocational instruction. To be effective, numeracy support needs to be delivered as it is required for the instructional or vocational task at hand. This ensures that the numeracy delivered is "wholly and immediately relevant" (Bates, 2005, p. 26) to learners and helps them to achieve success in the vocational area. Ideally, numeracy support is provided as learners are engaged in a practical task, rather than in a separate classroom and at a different time. However, separate provision of numeracy can be effective if it is closely linked to the vocational learning and taught by tutors that clearly understand and articulate these links.

Once the connections between numeracy and vocational learning have been established, it is important for all aspects of the teaching and learning programmes to reflect these links. In particular, learning materials will be more relevant for learners where these links are clear and differentiating these materials for learners' varying LLN needs will increase their accessibility.

Implications for practice

Vocational programmes will more effectively integrate numeracy learning where:

- there are clear and explicit links between vocational and numeracy content
- both vocational and numeracy tutors understand the ways in which numeracy is used in specific vocational tasks and activities
- both vocational and numeracy tutors understand the numeracy requirements of the learning environment
- numeracy instruction is delivered as it is required for vocational learning
- the connections between numeracy and vocational learning are clearly evident in teaching materials
- teaching and learning materials are differentiated for learners' varying numeracy needs.

References: Bates (2005); Casey et al. (2006); Cranmer et al. (2004); NRDC (2006); Roberts et al. (2005).

> Effective assessment in programmes where numeracy is embedded makes use of learning progressions to provide direction for teaching programmes and to monitor progress toward learning goals.

Research findings

Learning continuums, or progressions, clearly describe the growth of knowledge and skills that occurs as learners develop their expertise in a particular area. Effective progressions focus on more than the acquisition of facts or isolated skills; they describe important aspects of learning that distinguish novice from expert. This includes a wide range of developing skills and abilities, the fluency and independence with which new skills can be applied and the range of situations they can be applied to. Where vocational courses have clearly described learning progressions that are consistent with the goals of the programme, they can be used to help ensure students' developing knowledge is relevant to the vocation they are training for and useful in achieving their purposes.

Learning progressions provide valuable direction for teaching programmes. Effective diagnostic assessment establishes where a learner is initially placed on the progression by identifying their current skills and understandings. Teaching can then be directed towards developing the knowledge required to move the learner along the progression. As teaching continues, formative assessment provides information about a learner's progress towards learning goals.

Successful embedded numeracy provision makes use of diagnostic and formative assessment procedures to provide both formal and informal feedback to learners about their progress. Where learners have a clear picture of their current skills and next learning steps in relation to their learning goals, they are more likely to feel motivated and confident about their learning.

Researchers in adult numeracy education consider there to be a lack of effective assessment instruments available. They describe the need for the development of meaningful forms of assessment that focus on the development of real skills rather than requiring respondents to answer more formal types of test questions.

Implications for practice

Effective assessment procedures:

- make use of learning progressions that clearly describe how learners' knowledge and skills will grow as they develop their expertise

- use diagnostic assessment information to establish where a learner is initially placed on the learning progression by identifying their current skills and understandings

- use formative assessment to monitor learners' progress towards learning goals

- provide formal and informal information to learners about their progress.

It would be beneficial to develop effective assessment instruments for use in adult numeracy education.

References: Bingman & Stein (2001); Casey et al. (2006); Coben (2003); Cranmer et al. (2004); Cumming & Gal (2000); Stities (2002); Swain et al. (2005); Tertiary Education Commission (2008a); Tertiary Education Commission (2008b); Torgerson et al. (2004).

> Embedded numeracy provision is facilitated by appropriate organisational policies, management structures, resourcing, and working conditions.

Research findings

Embedded numeracy provision is more likely to be successful in institutions which adopt a whole-organisation approach to the development and support of embedded programmes. In particular, researchers agree on the importance of managerial support in the development of successful programmes.

> "Support for embedding from senior and middle managers through institution-wide policies makes it easier to direct resources in ways that will support embedded LLN." (Casey et al., 2006, p. 32)

The importance of organisational policies, management structures, resourcing, and working conditions aligned with effective practice is well recognised in the literature.

If changes at the individual level are not encouraged and supported at the organisational level, even the most promising innovation will fail (Guskey, 2000, p. 21).

Research focused on the development of effective practices to support embedded provision provides some examples of the practical ways organisations can support embedded numeracy learning. In particular, appropriate course documentation, organisational policies such as professional development and staff promotion policies, job descriptions and performance management systems have been identified as important. More practical constraints such as timetables, teaching spaces, and teaching and learning resources have also been identified as factors which support the provision of embedded numeracy programmes.

Implications for practice

Organisations can support the effective provision of embedded numeracy programmes by ensuring:

- entry requirements for vocational courses clearly specify required numeracy

- course objectives and goals incorporate both numeracy and vocational goals

- the professional development policy supports numeracy tutors to increase their understanding of the vocation, and vocational tutors to increase their understanding of numeracy

- the staff promotion policy incorporates aspects of numeracy learning

- job descriptions clearly define the different roles of teaching staff in delivering embedded programmes

- performance management systems reflect the importance of numeracy within vocational programmes

- timetabling allows for aspects of team work and sufficient contact time

- teaching facilities and equipment are distributed to support both numeracy and vocational learning.

References: Casey et al. (2006); DfES Skills for Life Strategy Unit (2005); Govers (2008); Guskey (2000); Roberts et al. (2005); Sagan et al. (2005).

4   SUSTAINING CHANGE TO ACHIEVE LONG-TERM EMBEDDING OF NUMERACY

> Organisations are more likely to develop and maintain effective approaches to embedding numeracy when the value of LLN is understood and numeracy is viewed as an integral part of vocational training.

Research findings

Senior managers play a key role in the development and maintenance of embedded numeracy programmes. When managers understand that embedded numeracy is effective in increasing participation and raising achievement, approaches are more likely to be sustained. In addition to understanding the benefits of embedded numeracy, it is important for managers to "fully understand the implications of embedding, both in terms of the practical support it requires but also in terms of pedagogy and teachers' expertise" (Casey et al., 2006, p. 45). Where managerial support is provided, the effective embedded approaches developed by committed and enthusiastic tutors are more likely to be used by other tutors.

Numeracy teaching is more likely to be effective when it is regarded as an integral part of vocational training. This is in contrast to approaches that view numeracy as optional, required only by those learners that need additional learning support.

> "Learners improve their literacy, numeracy and other key skills when the whole organisation believes key skills are an essential underpinning for learning vocational skills and technical knowledge." (Cranmer et al., 2004, p. 4)

Positioning numeracy as an essential part of vocational training reduces the stigma associated with needing assistance, so learners are more likely to succeed.

Learners who appreciate the value of LLN skills for their future career opportunities are more likely to be motivated and achieve success. Tutors and employers play a key role in communicating the value of numeracy skills to learners. Vocational tutors are more likely to be able to effectively communicate the value of LLN skills to learners with regard to their career aspirations because they "…have a natural legitimacy… in the eyes of the learners [as] they represent the role to which the learner aspires" (Roberts et al., 2005, p. 9). Employers also play a key role in communicating the value of numeracy to learners. The active involvement and support of employers increase learner motivation and engagement.

Implications for practice

Effective embedded approaches to numeracy are more likely to be developed and maintained when:

- managers understand that embedded numeracy is effective in increasing participation and raising achievement

- numeracy is regarded as an integral part of vocational training, rather than additional support for those with particular learning needs

- tutors effectively communicate the value of numeracy to learners with regard to their future career opportunities

- employers are actively involved in learning and support attendance.

References: Bates (2005); Casey et al. (2006); Cranmer, Kersh et al. (2004); NRDC (2006); Roberts et al. (2005); Sagan et al. (2005); Swain et al. (2005).

> Teaching materials are important tools that can substantially influence the content and enactment of instruction.

Research findings

Teaching can be understood as a process of design.

> "Teachers perceive and interpret existing resources, evaluate the constraints of the classroom setting, balance tradeoffs and devise strategies – all in the pursuit of their instructional goals." (Brown & Edelson, 2003, p. 1)

Within this view, curriculum materials are a tool used by tutors as they design instructional programmes. The ways in which teachers use learning materials are dependent upon their own understandings, the understandings and characteristics of the students they teach, and the contexts of instruction. Where teachers have a sound understanding of content, they tend to improvise instruction, devising learning activities independently from teaching resources. Contrastingly, where teachers lack understanding, they offload responsibility for student learning onto teaching materials, following set instructional activities and sequences. Between these two extremes, teachers adapt learning programmes by modifying teaching materials to better address student needs, fit with their teaching style, or align with classroom circumstances.

Researchers in this area use the term 'enacted curriculum' to acknowledge the difference between the teaching and learning that take place in the classroom and the teaching and learning intended by content frameworks and the developers of teaching materials. This term acknowledges the active role of teachers in designing instruction; "…the enacted curriculum is actually jointly constructed by teachers, students, and materials in particular contexts" (Ball & Cohen, 1996, p. 7).

Because teaching materials directly influence the process of teaching, they have been widely used as a tool in instructional reform.

> "A primary lure of curriculum materials is that, of all the different instruments for conveying educational policies, they exert perhaps the most direct influence on the tasks that teachers actually do with their students each day in the classroom." (Brown & Edelson, 2003, p. 1)

Researchers evaluating the effectiveness of such reforms stress that "…the materials themselves matter in teacher interactions with curriculum materials…" (Remillard, 2005, p. 240). They outline that curriculum materials need to be developed in ways that clearly anticipate the role of the teacher in curriculum design. In particular, teaching materials need to include important information that enables teachers to make decisions about how and when to use the material presented. This information may include descriptions of content, effective ways to represent key concepts and the benefits and limitations of these, and information about probable student responses and the reasoning behind these.

Implications for practice

Effective teaching materials will anticipate the role of the teacher in curriculum design and therefore:

- include descriptions of important content knowledge

- include important representations that can be used to communicate key content to students and provide information about how these can be used in teaching

- include information about probable student responses and the reasoning behind these

- include information about the ways in which aspects of learning are related, both in terms of conceptual ideas and across time

- are relevant to tutors' current understandings

- are written and presented in ways that communicate effectively with tutors.

References: Ball (1990); Ball & Cohen (1996); Ben-Peretz (1990); Brown & Edelson (2003); Cohen & Ball (1999); Pea (1993); Remillard (2005); Schmitt (2000); Sherin & Drake (2004); Spillane (2006).

> Professional development programmes can be effective in improving tutor practice and learner performance.

Research findings

Effective professional development programmes focus clearly on the link between learning and tutor practice. As an outcome of such programmes, tutors understand the ways in which their own practice affects the learning that occurs in their classrooms. "The core question is, what do we as teachers need to do to promote the learning of our students?" (Timperley, 2008, p. 11).

Efforts to improve instruction are most likely to produce genuine changes to practice when programmes are focused on developing the professional knowledge base of tutors. Tutors require a comprehensive knowledge of the subject, an understanding of how to teach key concepts effectively, and an awareness of how to assess learners' progress in the area.

> "Successful professional development efforts are those that help teachers to acquire or develop new ways of thinking about learning, learners, and subject matter, thus constructing a professional knowledge base that will enable them to teach students in more powerful and meaningful ways." (Borko & Putnam, 1995, p. 60)

By contrast, where tutor knowledge is not engaged and extended in professional development programmes, participating tutors are likely to adopt surface features of the new approach while maintaining the core content of their previous practice. While information about the knowledge and skills of those teaching adult numeracy is limited, it points to relatively low levels of mathematics knowledge and achievement amongst adult numeracy tutors.

Effective professional development programmes provide opportunities for tutors to connect their professional learning with their current understandings and approaches. Because "…teachers' knowledge and beliefs affect how they perceive and act on various messages about changing their teaching" (Borko & Putnam, 1995, p. 59), effective programmes support tutors to clarify their own understandings as they build a professional knowledge base. Effective programmes also address the contexts in which participating tutors work. New approaches are introduced in a way that "is consistent with the principles of effective teaching but also systematically assists teachers to translate those principles into locally adapted applications" (Timperley, 2008, p. 9).

Research suggests that when tutors are involved in ongoing professional development programmes that are clearly linked to their current teaching situation, they are more likely to take greater responsibility for student learning and develop effective teaching practices.

> "Change appears to be promoted by a cyclical process in which teachers: have their current assumptions challenged by the demonstration of effective alternative practice, develop new knowledge and skills, make small changes to practice, and observe resulting improvements in student outcomes." (Timperley, 2008, p. 14)

Where tutors take responsibility for student learning, there is a sound basis for continual improvement to knowledge and practice.

Research into effective embedded numeracy provision highlights the importance of professional development for both vocational and numeracy tutors. In particular, vocational tutors need support to increase their understanding of learners' varying numeracy needs and develop their knowledge of how numeracy is used in vocational tasks. Numeracy tutors need support to develop teaching approaches that are guided by vocational content and recognise the role of numeracy in the vocation. Both vocational and numeracy tutors would benefit from professional development programmes that develop collaborative approaches to teaching.

Implications for practice

Professional development programmes are most likely to lead to improvements in tutor practice and learner performance when:

- tutors are supported to understand the ways in which their own practice affects the learning that occurs in their classrooms

- tutors are supported to identify and examine their current understandings and methods

- tutors are supported to implement new approaches in the specific contexts in which they work

- tutors have an increasing sense of responsibility for student learning

- programmes develop tutors' knowledge of content

- programmes develop tutors' understandings of effective pedagogy

- programmes develop tutors' knowledge of how to assess learners' progress

- programmes engage tutors in a range of learning activities: formal and informal, group and individual, planned and unstructured

- programmes involve tutors in an ongoing cycle of professional development

- programmes support tutors to make changes to practice and then observe the effects of these.

In effective embedded LLN approaches, professional development programmes:

- support vocational tutors to increase their understanding of learners' varying numeracy needs and develop their knowledge of how numeracy is used in vocational tasks

- support numeracy tutors to develop teaching approaches that are guided by vocational content and recognise the role of numeracy in the vocation

- support the development of collaborative approaches to teaching.

References: Askew, et al. (1997); Borko & Putnam (1995); Butler et al. (2004); Casey et al. (2006); Coben (2003); Franke et al. (1998); Guskey (2000); Morton et al. (2006); Roberts et al. (2005); Smylie (1995); Swain et al. (2005); Swain & Swan (2007); Timperley (2008); Wilson & Berne (1999).

> Assessment data provides valuable information that can be used systematically to improve programmes.

Research findings

Research into programme improvement highlights the value of achievement data in the process of improving instruction. Within this approach, the "achievement of student outcomes is the criterion for judging the effectiveness of all other programme practices and components" (Bingman & Stein, 2001, p. 23). Achievement data provides a measure of whether learners are successfully meeting learning goals, and this in turn provides information on the effectiveness of teaching programmes and other organisational practices. An effective model of continuous programme improvement requires organisations to clearly specify learning goals, systematically monitor the progress of all learners towards these goals and then revise teaching programmes on the basis of this information.

This approach is consistent with a learning paradigm perspective which views learning as the key responsibility of educational institutions, while the contrasting instructional paradigm emphasises the delivery of instruction as the primary duty of organisation.

> "…in the Learning Paradigm, the power of an environment or approach is judged in terms of its impact on learning. If learning occurs, then the environment has power... To know this in the learning paradigm we would assess student learning routinely and constantly." (Barr & Tagg, 1995, p. 17)

A learning paradigm perspective emphasises the importance of using both individual and aggregate measures of achievement in order to continuously improve the performance of both individual students and the organisation as a whole.

Professional learning communities can successfully effect and sustain change by highlighting learner performance. When tutors work collaboratively to reflect on achievement data and modify teaching approaches "…the entire team gains new insights into what is working and what is not, and members discuss new strategies that they can implement in their classrooms to raise student achievement" (DuFour, 2004, p. 10).

Implications for practice

Organisations are more likely to engage in ongoing cycles of improvement when systems are established to review achievement information regularly.

The use of assessment data to systematically improve programmes is facilitated when:

- learner performance goals are clearly defined

- effective assessment methods are in place to measure progress towards learning goals

- achievement information is regularly aggregated and analysed

- tutors work collaboratively to reflect on achievement data and modify teaching approaches appropriately

- instructional programmes and organisational practices are adapted on the basis of insights gained from assessment information.

References: Barr & Tagg (1995); Bingman & Stein (2001); DuFour (2004); Levesque et al. (1996); Timperley (2008); US Department of Education (2003).

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