Martin, L., and Towers, J. (2012). "Some Guys Wouldn't Use Three-Eighths on Anything...": Improvisational Coaction in an Apprenticeship Training Classroom. *Adults Learning Mathematics: An International Journal, 7*(1), 8-19.

"Some Guys Wouldn't Use Three-Eighths on Anything...": Improvisational Coaction in an Apprenticeship Training Classroom

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Abstract

This paper presents some ongoing findings from a larger project exploring the growth of mathematical understanding in a variety of construction trades training programs. In this paper we specifically focus on the notion of collective mathematical understanding in an ironworking apprenticeship classroom. We identify the particular ways in which a group of three apprentices work collaboratively together to solve a workplace problem with a substantial mathematical element. Through drawing on the notion of 'improvisational coactions' (Martin & Towers, 2009) we detail the ways that individual ideas, understandings and contributions mesh together and are collectively built on by the group to allow a shared understanding to emerge. From this analysis we suggest that improvisational coactions can be a powerful means through which apprentices in the workplace-training classroom might effectively learn to tackle workplace problems that involve thinking and working mathematically. Although our conclusions are specific to this case, we would suggest that there are implications that may be relevant to other areas of workplace training.

Key words: mathematics; group work; improvisation; workplace; learning.

Introduction

FitzSimons, Micek, Hull, & Wright (2005) note that "current research positions numeracy as a social and cultural-historical process – to use terms drawn from activity theory" (p. 9). As a consequence of such a theoretical framing, increased attention is being paid to collaborative actions as an important aspect of both workplace learning and practice. For example, Boyer and Roth (2006), in researching the learning that emerged for participants in an environmental action group, noted "much of their learning occurs informally, simply by participating in the everyday, ongoing collective life of the chosen group" and "changing forms of participation are emergent features of unfolding sociomaterial inter-action, not determinate roles or rules" (p. 1028).

Drawing on the notion of 'funds of knowledge' (Baker & Rhodes, 2007; Gonzalez, Andrade, Civil, & Moll, 2001)—the informal, broader knowledge and experiences that adult learners often possess—Oughton (2009) talks of the need for learners to "admit doubt, challenge each other's responses, and support each other in group activities" (p. 27). She further highlights that, in her study into learning in an adult numeracy class, "parts of the data show how the students share and pool metacognitive strategies such as eliminating easy possibilities first, and using different forms of visualisation" (p. 27).

O'Connor (1994) recognises that ethnographic studies also "emphasise that the nature of work itself is collective, and almost always requires the informal collective interaction and action among individuals" (p. 281), a view taken up by FitzSimons, Micek, Hull & Wright (2005) who state that "as an activity, work is a collective process, dependent on interaction and communication, using artefacts, such as tools, written materials, tables and charts, as an integral part of the process" (p. 9). More specifically, and of significance for learning, they suggest that "the communal model which operates has greater depth than any individual knowledge base; the group develops a communal memory of problems and solutions, and provides assistance to individuals—a valuable and relevant learning asset" (FitzSimons, Micek, Hull, & Wright, 2005, p.23). It should however also be noted that as FitzSimons, Micek, Hull, & Wright (2005) state "there has been little attention until now focused on how numeracy is learned in the workplace, taking into account the complex issues which surround apparently simple calculations, and the importance of social, cultural, and historical contexts" (p. 26).

In this paper, by discussing the case of three apprentice ironworkers, we explore the process through which a communal model is seen to emerge and be fostered from the social context and interactions of the group as they work together on a workplace task with a strong mathematical component. In doing this we draw on a framework of improvisation, in particular the notion of 'improvisational coactions' (Martin & Towers, 2009), a perspective and analytic tool that allows us to identify the emergence of a collective understanding of the workplace task and the associated mathematical ideas. This collective understanding is, we suggest, the means through which the three apprentices are able to successfully engage with and complete the task, in ways that would not perhaps have been possible individually.

Improvisational coactions and collective understanding

In recent papers (Martin, Towers, & Pirie, 2006; Martin & Towers, 2009) we offered the beginnings of a theoretical framework focussing on the collective mathematical activity of learners collaborating in small groups. We demonstrated that by using the analytic lens of improvisational theory it was possible to observe, explain, and account for acts of mathematical understanding that could not simply be located in the minds or actions of any one individual, but instead emerged from the interplay of the ideas of individuals, as these became woven together in shared action, as in an improvisational performance.

Improvisation is broadly defined as a process "of spontaneous action, interaction and communication" (Gordon Calvert, 2001, p. 87). Ruhleder and Stoltzfus (2000), in talking of the improvisational process, draw attention to "people's ability to integrate multiple, spontaneously unfolding contributions into a coherent whole" suggesting that many of our everyday actions and interactions are improvisational in nature (p. 186). Influenced by the literature that focuses on improvisational action in the fields of jazz and theatre we have developed the theoretical construct of "improvisational coaction". Sawyer (2003) talks of improvisational activity as being conceived of "as a jointly accomplished co-actional process" (p.38) and for us the use of the term coaction rather than simply interaction emphasises, in a powerful manner, the notion of acting with the ideas and actions of others in a mutual, joint way.

Improvisational coaction is a process through which mathematical ideas and actions, initially stemming from an individual learner, become taken up, built upon, developed, reworked, and elaborated by others, and thus emerge as shared understandings for and across the group, rather than remaining located within any one individual. We identify four specific characteristics of the phenomenon: No one person driving; An interweaving of partial fragments of images; Listening to the group mind; and Collectively building on the better idea (Martin & Towers, 2009). It is these characteristics that we employ in our analysis of extracts of videodata to explore the process through which collective understanding emerges for the three apprentice ironworkers. Although full definitions of the characteristics can be found in Martin & Towers (2009) we offer here brief descriptors that help to situate the interpretation of our data extracts through this lens.

No one person driving

In improvisational theatre, the term driving refers to an actor who is taking over the scene by preventing other actors from having an opportunity to contribute to the emerging direction of the performance (Sawyer, 2003, p. 9). In contrast, no one person driving suggests a more distributed kind of collaboration, where no single person dominates or controls the emerging action. In the context of mathematics we suggest that this is observed where no one learner in the group is individually able to contribute a coherent, clearly articulated solution to the mathematical problem. Instead, learners need to work collectively as their individual images are partial and they require offerings from others to complete them (see next section for an elaboration of this idea). Thus, there is an absence of a 'driver' (in the sense of a single, continually mathematically dominant person). This need for the collective and the lack of a dominant leader is in sharp contrast to some other data examples we have presented (Martin & Towers, 2010), wherein a mathematically stronger (or socially more powerful) learner dominates the process. While the learners in those episodes interact, they do not improvisationally coact.

An interweaving of partial fragments of images

In talking about musicians, Monson (1996) wrote:

> When you get into a musical conversation, one person in the group will state an idea or the beginning of an idea and another person will complete the idea or their interpretation of the same idea, how they hear it. So the conversation happens in fragments and comes from different parts, different voices. (p. 78)

We see a similar evolution of mathematical ideas in the growth of collective mathematical understanding, where fragments of mathematical ideas (or images) initially offered by individuals become acted upon by others and coalesce into a shared (or distributed) image for the group. It is just not the fact that different learners are offering partial (or incomplete) images that is important for the collective growth of understanding, but also that others in the group choose to take these up and add to them. The following two sections elaborate this adding to and building upon in greater detail.

Listening to the group mind

Although it might appear that improvisational performances are unscripted and that 'anything goes' this is not the case, and a number of conventions govern the ways in which an improvisational performance develops. Becker (2000) notes the importance that everyone pays attention to the other players and be willing to alter what they are doing "in response to tiny cues that suggest a new direction that might be interesting to take" (p. 172). In terms of mathematics, such a cue would likely involve the offering of some new (perhaps partial) mathematical idea or a possible strategy or approach to take to a problem in order to proceed.

The notion of listening to the group mind (Sawyer, 2003, p. 47) places a responsibility on those who are positioned to respond to an offered action or innovative idea as much as on the originator, and it is this process wherein the group collectively determines whether, and how, the idea will be accepted into the emerging performance, that we suggest is the key to the emergence of a collective understanding.

Collectively building on the better idea

One implication of listening to the group mind is that when one person does or offers something new that, in the view of the group, is likely to be a useful idea or strategy to collectively pursue, then "everyone else drops their own ideas and immediately joins in working on that better idea" (Becker, 2000, p. 175). This collectively building on the better idea is key to how collective understanding actually grows through coaction. Of course this requires some understanding of what 'better' might look like and of how to recognise it. In mathematics a 'better idea' is one that (at that moment) seems to be a different, new, more powerful way to proceed. Again, the better idea might be a new piece of mathematics or an alternative way to think about the problem—this is established through listening to the group mind and is then collectively acted upon.

The case of Joe, Andy, Mike, and the ironworking task

The larger study, from which the data in this paper is drawn, is made up of a series of case studies of apprentices training towards qualification in various construction trades in British Columbia, Canada. From these case studies we are continuing to develop a series of 'stories of understanding' which seek to identify and elaborate the often complex process through which apprentices engage with mathematics in the workplace training classroom (e.g., Martin & Towers, 2007; Martin, LaCroix, & Fownes, 2005, 2006). The case studies involved video recorded observations, together with field notes and interviews with selected apprentices. Data was collected in the training classroom and workshop. Both whole classes and smaller groups of learners were observed, depending on the structure of the session. In observing and analysing the ways in which the apprentices used their mathematical knowledge in the context of workplace tasks we drew on the approach proposed by Powell, Francisco, & Maher (2003) allowing us to construct a series of emerging narratives about the data, of which this perspective on collective action is one.

To illustrate the role, and power, of improvisational coacting in the growth of understanding in the workplace-training classroom, we will consider the case of three apprentices, known as Joe, Andy and Mike, and their engagement with a workplace task. The apprentices are in the second year of an apprenticeship-training program to become credentialed ironworkers. Their training course is part time, and, when not in college, they are employed full time for various companies in different parts of British Columbia, Canada. The taught program is based in an Institute of Technology in Burnaby, BC, and involves classroom and practical sessions. In this session Joe, Andy and Mike have been posed the task of establishing the size of choker sling required to lift an assembled structure of four large iron beams into an upright position, and later of determining where the crane should be positioned to accomplish this. Figure 1 illustrates this actually being carried out.

Figure 1. The four beams, assembled and being lifted.

The structure consists of two upright beams, one top crosspiece, and one middle beam, which are welded together on the ground and then hoisted into an upright position. As can be seen in the photograph, this T-shape piece is lifted into position using two chokers in a sling arrangement around the top beam. It is the size of these chokers (i.e., the diameter of the cable, in inches) that the apprentices have been asked to calculate, something that is dependant on the total weight of the structure to be lifted (i.e., the total weight of the four beams).

The data being discussed here were drawn from a classroom session where the apprentices worked with technical plans to determine the appropriate configuration prior to its practical implementation. The apprentices were in a larger class of about twenty students and Joe, Andy, and Mike worked closely together, for about one hour, at a desk, where they were video and audio recorded. A researcher acted as an observer to the session and made appropriate notes. The extracts of data offered here, analysed through the interpretive framework of improvisational coactions, illustrate the way in which a collective understanding (of both the task and the mathematics required by it) emerges and grows for Joe, Mike, and Andy, and how this allows them to successfully choose a choker of the appropriate size.

Extract One – Length of the choker

The first part of the task required that the group calculate the total weight of the structure to be lifted (i.e., the sum of the weights of the four beams). Just prior to the start of the extract below the apprentices have completed this calculation, finding firstly the total weight in kilogrammes (seven hundred and twenty-seven kilogrammes) and the converting this to pounds by multiplying by two point two (giving one thousand, six hundred, and twenty-one point four pounds). They are now moving on to determine the size of choker required to safely lift the structure. They have chosen to use a rigging structure involving two chokers. This kind of choker hitch is shown in figure two.

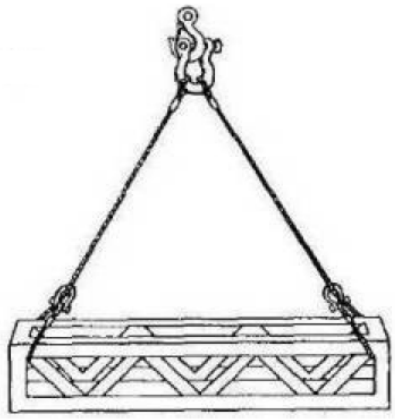

Figure 2. A two-choker sling arrangement lifting a beam.

They now need to decide where to place the chokers on the top beam, choose the length of each cable, calculate the vertical height of the triangle created by the two chokers (commonly known as the “vert”), and then find the stress in each choker. To find this stress they employ a commonly used formula: $\frac{m}{n} \times \frac{l}{v}$ where *m* is the total mass to be lifted; *n* is the number of chokers; *l* is the length of each choker; and *v* is the vertical height. This stress then determines the choker size, i.e., the diameter of cable that is safe to use for lifting the structure.

1 Andy: The length, eh? We can find out the length.
2 Mike: What? Choker length?
3 Andy: Yeah.
4 Joe: ‘Cos we’re going to choke it here and here (*he indicates two points near the end of the top beam*)
5 Mike: We can just give it a length if we want to
6 Andy: No you can’t
7 Mike: Why not?
8 Joe: Yeah for a scenario, just give it a length of…what’s this distance from here to here again? (*He is referring again to the length of the beam*)
9 Mike: Three thousand and forty eight (*this is the distance in millimetres between the two points*).
10 Andy: Three metres.
11 Mike: Three and a half metres.
12 Joe: Three and a half metres.
13 Mike: So we want to be about three and a half metres up?
14 Mike: All sides we want to equal around the same, right?
15 Joe: Exactly. Yeah. Right, have to make a triangle.
16 Mike: So you can make that into footage, three point zero four eight.
17 Andy: Ten feet.
18 Mike: Yeah. Ten-foot chokers it is.
19 Andy: Ten feet chokers.
20 Mike: How many fee..
21 Joe: What do you want?
22 Andy: How many feet in a metre? Three point..
23 Mike: Yeah. It is ten feet times three point two eight oh eight. Yeah. Ten feet.
24 Andy: Ten feet.
25 Mike: Ten-foot chokers.

26 Andy: Pretty much exactly.
27 Mike: So we got ten foot.

The apprentices start with clarifying among themselves exactly what they are being asked to do. Andy points out that they can find the length, Mike refines this to choker length and Joe indicates how finding this will help in the actual lifting of the structure. Mike then suggests that they could just choose a length. In theory, this is not incorrect as different lengths will simply lead to different angles being created between the top beam and the two chokers (different shaped triangles is another way to visualise this). Andy rejects this idea, but it is then picked up on by Joe who suggests choosing a length equal to that of the top beam (three thousand and forty-eight millimetres). As Mike then expresses it, "all sides we want to equal around the same, right?" Although not essential, it is common practice in the workplace, for safety reasons, to choose cable lengths that will generate an equilateral triangle, as this minimizes the stress in each cable, and it is this idea that they then use as they calculate the length of each choker. They decide to switch to using imperial measures, and so work with 'ten foot' as the chosen length. Following a brief check of this conversion they agree that ten-foot chokers will be their chosen length. This decision, and agreement, to use ten-foot chokers arranged to give an equilateral triangle is not one that is instantly arrived at, nor merely stated by one apprentice in the starting of the task. Instead we see all three contributing ideas about possible ways to proceed and these partial ideas and offerings interweave as the conversation develops, leading to a collective image for an appropriate rigging design. No single apprentice dominates the conversation or is able to simply calculate the choker length. The notion of forming an equilateral triangle, although initially posited by Joe (line 8) is one that is collectively built on as a better idea (lines 9-16), and frames the calculation that follows, which is also carried out by an interweaving of partial contributions, leading to the accepted answer, by the group, of 'ten foot'.

Extract Two – Finding the vert

The next stage in determining the correct size of choker is to use the formula $\frac{m}{n} \times \frac{l}{v}$. They have now calculated *m, n* and *l*, and need to find *v*, the vertical height of the equilateral triangle created by their chosen choker arrangement.

28 Joe: So that's our vertical (*referring to the ten feet just calculated)*?
29 Mike: No.
30 Andy: Yeah. So if we got our bottom distance and top distance.
31 Joe: You just say m over n times l over v, that's what he wants for this (*referring to the course instructor*).
32 Andy: So one thousand six hundred and twenty four (*this is the total mass of the structure*).
33 Joe: Yeah. One thousand six hundred and twenty one.
34 Andy: Over two. But what would the vert be?
35 Joe: We've got to do that.
36 Mike: We're going to find it out right now. Okay, this is going to be half of it right here (*he indicates the mid-point of the base of the triangle*). Four point nine, nine, nine, feet.
37 Andy: That's half of ten.
38 Mike: Just do some trigonometry. Just go ten squared minus five squared.
39 Joe: (*starts working on calculator*) Five?
40 Mike: Yeah. Minus five squared.
41 Joe: Square root of five, seventy-five (*he continues to work on the calculator*). Eight point six.

42 Mike: That's how high it is then.
43 Andy: That's our vertical?
44 Joe: Yeah, sounds right.
45 Andy: Sounds good man.
46 Mike: F..k yeah.

At the start of this extract Joe initially thinks that ten feet is the vertical distance. Mike says no, and Andy elaborates. In talking about 'top' and 'bottom' distance we suggest he is referring to the base and hypotenuse of the created triangle. Joe (line 31) shows that he accepts and is willing to build on this better idea by introducing the required formula for calculating the stress on each choker and they consider which parts of this formula they know (the total mass, the number of chokers and the length of each). Andy asks what the missing number, the "vert", would be and Joe points out that they have to calculate this. Mike then proceeds to start the calculation–he mentions trigonometry (though he is going to use Pythagoras' Theorem) but gets Joe involved in performing the actual calculation. Although initially Joe simply seems to be 'number crunching', this is not the case. In line 41 he demonstrates that he understands the need to find the square root of seventy-five and offers the answer of eight point six. The process of deciding what to find, and then the subsequent calculation is not performed by one apprentice, but instead through the collective offering and building on partial elements of what is needed. Again, we see the other two apprentices reflecting on the answer and ensuring that they know what they have found and that it is appropriate. It is not simply accepted as correct, but instead there is an explicit and articulated checking that there is a collective, shared image here. Andy clarifies that this is "our vertical" (line 43) and Joe and then all three, in different ways, offer statements to confirm that the answer "sounds right" or "sounds good". As shown in the transcript, Mike expresses his satisfaction slightly differently (line 46).

Extract Three: Size of the choker

With the four required measurements the apprentices then quickly calculated the stress for the rig. Having obtained the (correct) answer of 936 lbs they now move to determine the size of the choker. This is a piece of information read from a published chart which provides the correct choker size for a given rigging configuration and stress.

47 Mike: Yes, so we'll be able to figure out what size choker we need.
48 Sarah: [*An instructor passes by to see how the group is progressing*] Yes, ok.
49 Joe: Three-eighths (*reading from the chart*)
50 Mike: Yes, it is three-eighths.
51 Joe: We'll go half inch…and that's in pounds.
52 Mike: 'Cos the piece we're going to be picking up is like this, column here, column here, big piece on top, little piece right there (*see figure 1*). Then we're going to sling it right there, sling it right there, just pick it up like that (*see figure 2*). Too easy, we won't have to do any fancy rigging or anything like that. 'Cos its not even that heavy.
53 Joe: No, it's not. So that's our choker stress, this is our rigging configuration. You want to go half-inch chokers or what?
54 Andy: Well, we don't have to, but
55 Joe: I don't like using three eighth chokers on something like that.
56 Andy: I wouldn't either, but like still, it's still
57 Sarah: Why?
58 Joe: 'Cos its kind of small. In the field you never know, so just play it safe.
59 Andy: So that's a safe working load right there isn't it, like one ton?

60 Joe: Yeah that's your workload limit there
61 Andy: Oh it is, eh?
62 Joe: 'Cos if you went three-eighths
63 Andy: But that's only half a ton, so we can use three eighths.
64 Joe: You could, yeah. Depends who you talk to. Some guys wouldn't use three eighths (*he looks at Mike*)
65 Mike: Yeah, some guys wouldn't use three-eighths on anything (*they all laugh*). We'll just say three-eighths though 'cos that's all we need here. What else do we have to find out?

In the above extract, using the rigging chart Joe reads off the value of "three-eighths" (of one inch). Mike agrees with this, and it might seem the task is solved and the appropriate size choker found. Interestingly though, Joe offers instead the better idea of "one half"—challenging the mathematically correct answer of "three-eighths" (and his own suggestion). This is a situation perhaps unique to the workplace, where it is not uncommon practice to choose a size larger than that required—for reasons of safety. Thus a correct answer is not necessarily an appropriate one. Mike listens to Joe's suggestion but doesn't agree and points out how simple the configuration is, and that the structure is not that heavy. At this point, it is not clear whether the group mind will accept the larger size as appropriate. Although Joe agrees with Mike's statement that the structure is not that heavy, he remains convinced of the need for half-inch chokers and re-presents this to the group, looking for the others to agree and to build on his suggestion. The coacting here is somewhat different to that seen in the previous extracts, as it is not strictly about the solving of a mathematical problem or the completion of a calculation. Instead, it is about the collective establishment of what is appropriate in the workplace.

Here too, the building on the better idea is also changed. It is not that Joe wants the group to add to his suggestion mathematically or to elaborate this. Instead it is more of a desire for there to be a shared understanding of *why* they should choose a choker of this size. He doesn't seem to be comfortable or willing to simply dictate to the group (and be a driver), but instead wants to enable a group consensus, to which all are committed. Andy then agrees that he doesn't like the smaller size of choker and when Sarah (a visiting tutor to the class) asks "why?" it is Joe who explains that it is safer "in the field" to use a larger size—even though the mathematical calculation suggests the smaller size will be adequate. Andy agrees, but again notes the weight of the structure (line 63). Joe accepts this, and also that this is usually a decision made by ironworkers as something of a matter of personal preference, and that "some guys wouldn't use three-eighths". It is then Mike who draws these ideas together for the group in a way that allows them to proceed through essentially acknowledging both choices as valid, but suggesting that here (in the context of a contrived, classroom task) three-eighths is a sufficient answer and the group continue to the next step. Although the data only allows us insight into this group's in-classroom mathematical practices, it does suggest that their choice might have been different were this an actual workplace task rather than a pencil and paper problem, and that a workplace choice might err on the side of safety rather than simply mathematical correctness.

Improvisational Coactions and Collective Understanding in the Workplace

As noted earlier, the nature of work is collective—involving and requiring individuals to be able to work together and to draw on each other's expertise and experience. In the data extracts above the group act with the contributions of other group members in a mutual, joint way that we characterise and explain through the lens of improvisational coaction. The way in which the group is able to mesh together fragments of each individual's knowing, through listening to the group mind, is what enables their collective mathematical understanding to grow, ultimately enabling them to complete the task successfully.

Their coaction occurs in two significant contexts. The first relates to the way the apprentices engage with, and generate, the mathematics needed in the task. Martin and LaCroix (2008) talk of “images of visible mathematics”—referring to the “conventional mathematical content that is taught and learned in the workplace training setting” (p. 127)—here this would include the formulas and calculations they employ in determining the choker length, the ‘vert’ and the choker size. No single apprentice ‘knows’ or ‘provides’ all of this mathematics, instead it emerges from an interweaving of partial fragments of images. The three apprentices need to share and build on partial mathematical ideas offered by each other to ensure that the group both uses appropriate mathematical formula and complete the required calculation correctly. Apprentices in trades like plumbing and ironworking are often not mathematically strong or confident, though this is not to say they are in any way mathematically incompetent. Our research suggests that their understandings seem to be partial, fragmented, specific and often deeply contextual. Collaborative working and coaction is one way through which such understandings become more complete, more general and more flexible, and as with Andy, Joe, and Mike, lead to correct and appropriate solutions to tasks and problems.

Also in these data we see a kind of coacting that is perhaps unique to the workplace—the process through which collective judgements are made about the reasonableness of the mathematical solution. The workings of Andy, Joe, and Mike are always underpinned by the overall purpose of the task—the *safe* lifting of a heavy, iron structure. As the extracts illustrate, there are many ways that the lifting of the iron beam structure could be accomplished, involving different kinds of hitches as well as different sizes and arrangements of the chokers. There is not just one correct solution, and it is the collective coaction that allows an appropriate decision and way forward to emerge from the working of the group—through listening to the group mind and collectively building on better ideas. However, these choices are not just mathematical questions and the context of the workplace is especially significant, as safety is always of paramount concern. The use of an incorrect choker would be dangerous, and thus ensuring both the choice of appropriate mathematics, the accuracy of any calculation *and* an awareness of the appropriateness of the answer is vital. As noted by Martin, LaCroix, and Fownes (2005), “in the school classroom, an incorrect answer will likely result in nothing more than a mark on a piece of paper, whereas in the workplace are real costs associated with such errors” (p. 23). On a building site involving large constructions, such costs may be human, as well as financial. Determining the appropriate choker size is not a task to be taken lightly.

Conclusion

Although it is recognised that work is a collective process, much of the instruction in the workplace-training classrooms (certainly those in which we worked) remains traditional in form and individual in focus. Some practical tasks are done collaboratively, but the kind of classroom described in this paper is an unusual one, having an organizational structure that requires group work and discussion. However, it is clear that such an approach to workplace learning can foster and stimulate powerful improvisational coaction, both around mathematical ideas and the way these are employed in the workplace. Such ways of working and thinking, as with Andy, Joe, and Mike, can generate a collective understanding that, as noted by FitzSimons, Micek, Hull, & Wright (2005), “has greater depth than any individual knowledge base” and through which a “communal memory” (p. 23) that also supports the idea that individual knowledge can emerge and be a powerful resource for learning and working. Groups that improvisationally coact not only have the capacity to work mathematically, and to solve problems, in ways that individually may not be possible, but also, through a process of continual verification and shared image making, to generate solutions that are less prone to incorrectness and error.

Acknowledgements

The research reported in this article is supported the Social Sciences and Humanities Research Council of Canada (SSHRC) through Grants #831-2002-0005, 501-2002-005, and 410-2009-0383. We thank the British Columbia Institute of Technology, Burnaby, B.C., and the course instructors for their assistance with this project, and acknowledge Andy, Joe, and Mike for their willingness to be involved in this study. We thank the B.C. Construction Industry Skills Improvement Council for their support of this research.

References

Baker, D., & Rhodes, V. (2007). *Making use of learners' funds of knowledge for mathematics and numeracy: Improving teaching and learning of mathematics and numeracy in adult education*. London: NRDC. Retrieved 5th January 2011 from http://www.maths4life.org.

Becker, H. (2000). The etiquette of improvisation. *Mind, Culture, and Activity, 7*(3), 171-176.

Boyer, L., & Roth, W.-M. (2006). Learning and teaching as emergent features of informal settings: An ethnographic study in an environmental action group. *Science Education, 90*, 1028-1049.

FitzSimons, G. E., Micek, S., Hull, O., & Wright, C. (2005). *Learning numeracy on the job: A case study of chemical handling and spraying. Final Report.* Adelaide: National Centre for Vocational Education Research.

Gonzalez, N., Andrade, R., Civil, M., & Moll, L.C. (2001). Bridging Funds of Distributed Knowledge: Creating Zones of Practices in Mathematics. *Journal of Education for Students Placed at Risk*, *6*(1&2), 115-132.

Gordon Calvert, L. M. (2001). *Mathematical conversations within the practice of mathematics*. New York: Peter Lang.

Martin, L. C., LaCroix, L. (2008). Images and the growth of understanding of mathematics-for-working. *Canadian Journal of Science, Mathematics and Technology Education, 8*(2), 121-139.

Martin, L. C., LaCroix, L., & Fownes, L. (2005). Folding back and the growth of mathematical understanding in workplace training. *Adults Learning Mathematics*, *1*(1), 19-35.

Martin, L. C., LaCroix, L., & Fownes, L. (2006). Flexible mathematical understanding in an ironworkers apprenticeship classroom. *Literacy and Numeracy Studies, 15*(1), 43-58.

Martin, L. C., & Towers, J. (2007). Improvisational etiquette and the growth of collective mathematical understanding. In T. Lamberg, & L. R. Wiest (Eds.), *Proceedings of the twenty-ninth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 457-464). Reno, NV: University of Nevada.

Martin, L. C., & Towers, J. (2009). Improvisational coactions and the growth of collective mathematical understanding. *Research in Mathematics Education, 11*(1), 1-19.

Martin, L. C., & Towers, J. (2010). Comparing interaction and improvisational coaction in mathematical collaboration. In Brosnan, P., Erchick, D. B., & Flevares, L. (Eds.), *Proceedings of the 32nd annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education IV (pp. 386-392).. Columbus, OH.*

Martin, L. C., Towers, J., & Pirie, S. E. B. (2006). Collective mathematical understanding as improvisation. *Mathematical Thinking and Learning*, *8*(2), 149-183.

Monson, I. (1996). *Saying something—Jazz improvisation and interaction*. Chicago, IL: University of Chicago Press.

O'Connor, P. (1994). Workplaces as sites of learning. In P. O'Connor (Ed), *Thinking work, vol.1: Theoretical perspectives on workers' literacies*. (pp.257- 295). Sydney: Adult Literacy and Basic Skills Action Coalition.

Oughton, H. M. (2009). A willing suspension of disbelief?: 'Contexts' and recontextualisation in adult numeracy classrooms. *Adults Learning Mathematics: An International Journal, 4*(1), 16-31.

Powell, A. B., Francisco, J. M., & Maher, C. A. (2003). An analytical model for studying the development of learners' mathematical ideas and reasoning using videotape data. *Journal of Mathematical Behavior* 22, 405-435.

Ruhleder, K., & Stoltzfus, F. (2000). The etiquette of the Master Class: Improvisation on a theme by Howard Becker. *Mind, Culture and Activity, 7*(3), 186-196.

Sawyer, R. K. (2003). *Group creativity: Music, theatre, collaboration*. Mahwah, NJ: Lawrence Erlbaum Associates.