CHAPTER 7

ANALYSIS OF A COMPONENT OF THE TASK: FULL-SIZE DRAWINGS FROM SCALE DIAGRAMS

In the previous chapter, descriptions were provided as to how each of the participants fabricated an offset downpipe. Initially, performances were divided into groups that consisted of like responses. The reason for these groupings was two-fold. Firstly, the degree to which the response made connections between similar features of the task, with the view to minimising time and effort for completion of that task, were examined. Secondly, the accuracy of the completed product was appraised.

Following the descriptive examination, the SOLO Model was utilised to provide a framework for the coding of the individual descriptive vignettes. The hierarchical nature of these results mirrored the groupings derived from the descriptive vignettes in the first section, but did so within a more objective and cognitively justifiable framework. Therefore, the SOLO Model was shown to provide greater insight into the cognitions involved in executing practical tasks.

However, it was evident that the strategies used by the participants were not the only factors influencing performance; there existed other aspects, which when placed together, enabled the apprentice to complete the task. As there were no workplace cues available, such as a house or other similar downpipes, the participants in this study chose to draw a diagram to full size to assist them in the fabrication. This approach was not prompted by the researcher as required for the solution process. This technique was taught in the TAFE college, and enabled the participants to obtain the cut-out measurement that would produce the required bend angle.

This chapter investigates the manner in which the participants drew full-size diagrams to help in their fabrication so as to explore Research Question 2: *Can the SOLO Model be applied as a framework to describe mathematical cognitive performance within workplace practice?* The structure of this chapter is similar to Chapter 6, and is divided into two sections. The first section furnishes the descriptive vignettes of each participant drawing the diagram to full size. The second section initially provides a task analysis leading to the expected SOLO levels for this performance. Following this, the participants' responses are coded using the SOLO Model.

Vignettes of Individual Performance

This section provides an overall description of each participant's performance relating to the drawing of a full-size diagram based on specifications provided in the Job Sheet (Appendix C). This aspect of performance was not requested. Possibly as a consequence of this, the approaches used differed between participants, for example, some completed the whole drawing at once, whereas others constructed their drawing as required at various times during the performance. A flow chart showing each participant's performance is provided in Appendix I.

The figures provided are photographs of drawings made by the participants. The lines that are drawn on the diagram by each participant are colour-coded both on the figures provided, and within the vignettes. The vignettes are presented, beginning with the first-year apprentices.

Anthony

Anthony's construction on the drawing was evident within two Key Performance Stages (KPS): the Setup, and the Second Bend. In the Setup KPS, Anthony "decided to measure it out ... how [it was done] at TAFE" because "it seemed to always work". Anthony's drawing is provided in Figure 7.1.

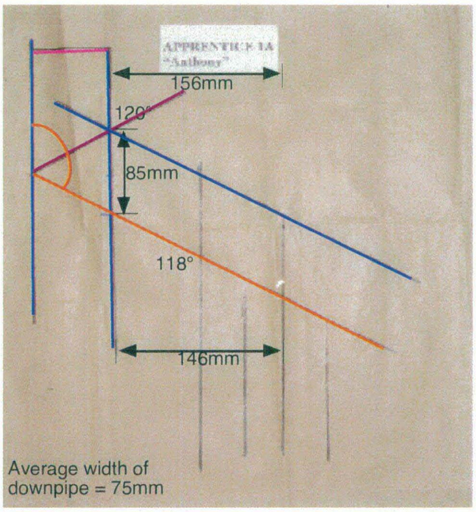

Figure 7.1. Anthony: Set-up drawing.

Anthony produced all **parallel lines** of downpipe width using the downpipe as a template. A **line** was drawn across the top of the downpipe using a set-square; the set-square was used to make the line perpendicular to the **parallel lines**.

Although interspersed with moments of hesitation, Anthony constructed the **diagonal offset line** using a protractor to obtain the 120° angle. This line was constructed at a mark 125mm from the top of the downpipe. Anthony also added **another line** using the protractor "to see how the angle was". This did not appear to be purposeful at the time of construction due to long periods of hesitation, along with verbal hesitation in the stimulated-recall interview. The drawing to this stage gave Anthony enough information to begin his fabrication of the first bend.

At the beginning of the Second Bend KPS, Anthony hesitated, commenting:

> I had to measure the 120 on the paper first. I suppose I could have used the angle I already did there, but I didn't know how I should have done it … now I do. I could have lined it (the downpipe) up where my centre line was on the downpipe, put it on that V there, and just marked it.

Anthony then began to draw the second bend to full size. To assist him in this activity, Anthony used the centre line already on his downpipe to draw the diagonal offset on his drawing at A (see Figure 7.2).

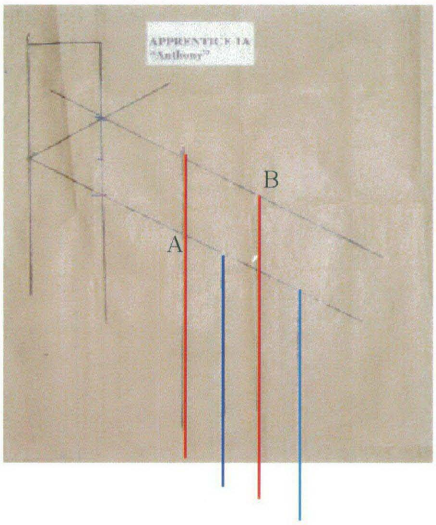

Figure 7.2. Anthony: Drawing second bend to full size.

Anthony then placed the downpipe on the offset mark on the paper and used it as a template to construct a second set of **verticals** from that mark, "just putting the downpipe there and just looking to see if it [visualising what the second vertical was going to look like] was parallel to the other lines out there". He commented that he "should have measured it to make sure the way the lines ... were parallel". The degree to which these lines were parallel to the first was done by visual estimation.

After some hesitation, Anthony said that he had transferred the centre line from his downpipe to the underside of the drawing at A, whereas he should have transferred them to the top side of the drawing at B. Anthony also drew a **line** to the right of A, not the left as required: "That's where I stuffed up ... I drew the lines in the wrong spot." Anthony then re-drew the second set of verticals using the downpipe as a template to get another set of **parallel lines.** He stated that "sometimes it takes a while to get through [his] head". Once these lines were completed, Anthony commented that he "can get the bend now, because [he has] got to cut it on the other side".

Bruce

Bruce drew the whole job to full size in the Setup KPS before beginning to fabricate the first bend. The drawing produced by Bruce is shown in Figure 7.3.

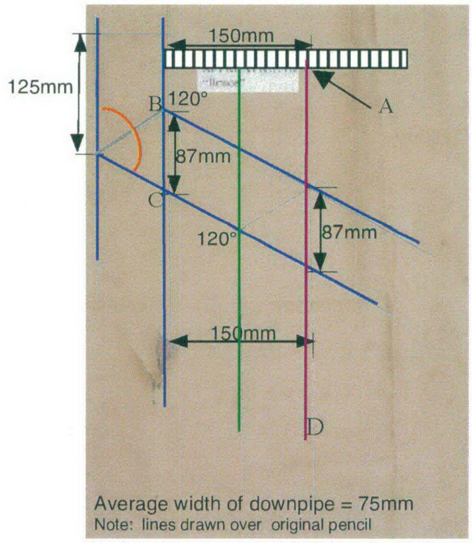

Figure 7.3. Bruce: Set-up drawing.

Bruce used the downpipe as a template to construct **parallel lines**, and employed a protractor to mark the **120° angle** from a point 125mm from the top of the left hand vertical line. Bruce estimated the degree to which distances were perpendicular using visual estimation, as opposed to using a set-square to provide a 90° angle. This method was also employed when establishing the offset distance of 150mm, at 90 from the first set of vertical lines. From this mark, the first **vertical offset line** was drawn. Bruce then used the downpipe as a template to make another **line** parallel to the vertical offset line.

To get the cut-out measurement, Bruce examined the distance BC, and measured it as 90mm. This distance was halved to obtain the cut-out measurement for the first bend. During the process of drawing the diagram to full size, Bruce did not verbalise any aspect of his performance, even though probes were provided initially to assist him to do so.

Chris

Chris drew his diagram to full size in two parts: the Setup KPS and the Offset KPS. In the Setup KPS, Chris drew the first bend only (see Figure 7.4).

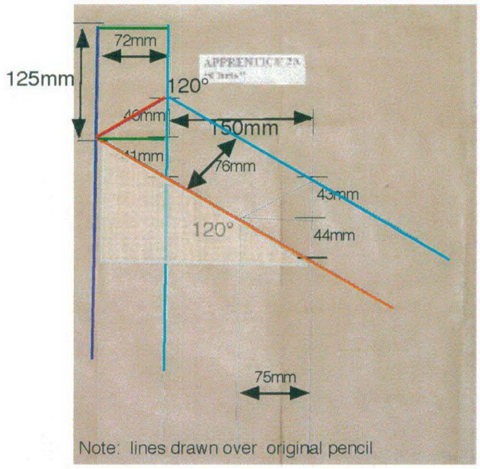

Figure 7.4. Chris: Set-up drawing.

Chris constructed parallel lines by first drawing **one line**, visually estimating two points at a distance of 75mm perpendicular to these lines with a ruler, and ruling another **line** through these points. He did not use the downpipe to generate parallel lines.

The **diagonal offset line** was constructed using a set-square rather than a protractor, from a point measured to be 125mm from the top of the downpipe. The 60° angle of the set-square was employed because he was "figuring out which was the 60 and which was the 30°, and then measuring off the centreline so [he could] make the 120°". A set-square was used to construct any **lines** which needed to be perpendicular. An additional **line** was constructed to acquire the cut-out measurement of 46mm. All measurements and angles were double checked "to make sure [they were] the right measurement before [he] cut out".

In the Offset KPS, Chris proceeded to complete the drawing before marking his offset on the downpipe (see Figure 7.5).

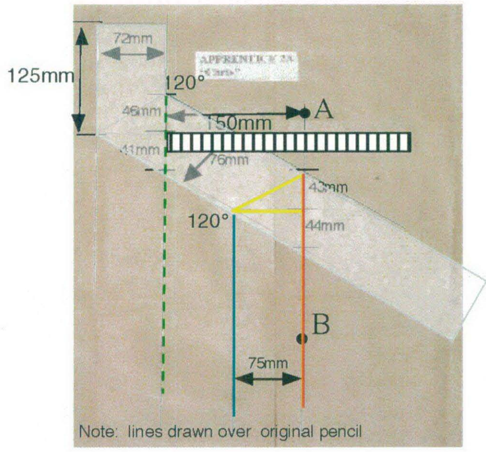

Figure 7.5. Chris: Drawing the offset and second bend to full size.

Chris began by measuring 150mm using a ruler from the **first verticals** with the addition that he used two marks at A and B 150mm from the first verticals and used these to make a **line** forming the second set of verticals for the downpipe. He stated that he was "just marking back 150 from the front to the back of the next angle, and so that was [his] back angle that's going to be up against the wall". In the same manner as for the width of the first verticals, Chris "measured back 75 to get [his] template again" to obtain a set of **parallel lines**.

To get the cut-out measurements for the second bend, Chris used the same method as for the first bend. **Lines** were constructed to calculate the measurement for the cut-out marks because he was "just doing exactly the same as what [he] did on the last one to make sure the cut-out's going to be the same, make sure [he had] got them both right". These distances were measured "to make sure". On the first bend, Chris used the measurement of 46mm. On the second bend, the measurement was found to be 43mm. He stated that "one of them was close … [he didn't] know if they were both meant to be the same, but one of them was".

With the downpipe on the drawing, a **vertical line** was transposed from the diagram to the downpipe. This was done to enable him to "keep going parallel down the downpipe so [he] could keep measuring 150 to the back of the other angle that was going to be up against the wall". With a ruler perpendicular to that green line by sight, Chris measured across 150mm and marked this on his downpipe for his centre line for the second bend. He did not use the measurements gained from the drawing to inform his offset on the downpipe.

David

In drawing his diagram to full size, David did not complete this task at once, but constructed aspects of it, as information to inform the fabrication was required. His performance was therefore divided up into the Setup, Offset and Second Bend KPSs.

In the Setup KPS, David only drew one bend. He used the downpipe as a template to construct the parallel lines, and the 60° angle of the set-square to draw in his angle for the offset line "because that there's a 60 ... which would give [him his] 120° angle". David did not measure a mark from the "top" of the downpipe on the drawing for the origin of this offset line. The cut-out line measured to be 46mm, and was found in a similar way to Chris.

From this point onwards, David's actions were interspersed with periods of hesitation in "making sure [the] angles [were] right ... measurements [were] right". Various combinations of two of the set-squares were arranged to inform the 120° angle already drawn to full size, "to see what angles [he] could get ... with those two angles ... you can pick 120 ... or you can do it just with a 60 sort of square". All measurements were re-checked multiple times. These deliberations are illustrated in Figure 7.6.

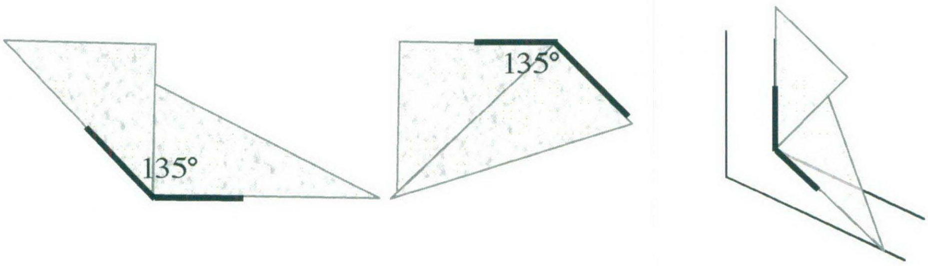

Figure 7.6. David: Set-up derivation of bend angle.

At the beginning of the Offset KPS, David commented:

> I'm just thinking ... to get, it says 150, the next part just on the paper to get it ... to get where I can mark it on the downpipe where the 150 is, sort of thing, because it doesn't have the measurement to come straight down that angle. So, I'll draw it up ...

A set-square was used to construct a **vertical line** to the far right of the paper (see Figure 7.7).

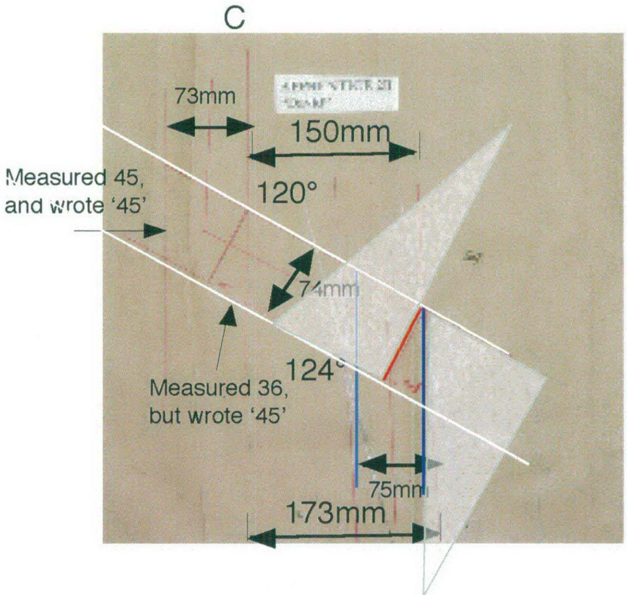

Figure 7.7. David: First stage of drawing the offset to full size.

This was a conscious procedure, carried out "a bit lower just to make sure it's going to be right". The downpipe was then used again as a template to draw in the **parallel line** of downpipe width. David used the set-square again to rule in a **line** to help find the cut-out measurement, although in the interview he mentioned that the "cut-out will be the same as the first one".

With a ruler, David measured "150 off the back of the downpipe". A mark was made 150mm across at C. At the beginning of the Second Bend KPS, David used the downpipe as a template, and two **vertical lines** were constructed (see Figure 7.8) emanating from the mark made only at C.

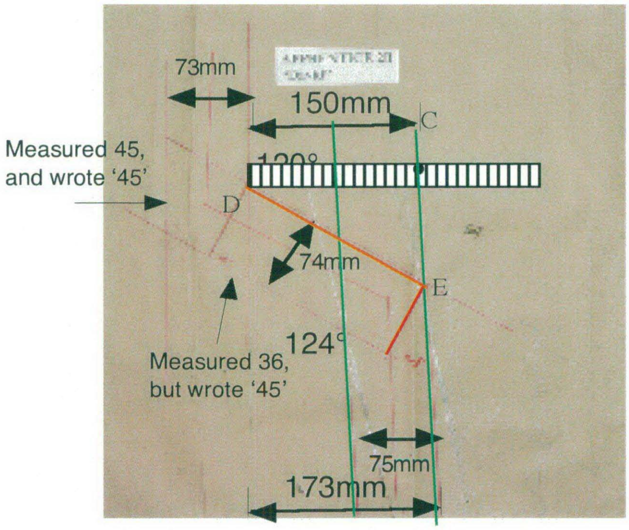

Figure 7.8. David: Second stage of drawing the second bend to full size.

The degree to which these lines were parallel to the first was estimated visually only. It was "square [to the first set because] you draw your line straight down … and you put a line or you get your downpipe on it". The previously drawn vertical lines on the far right hand side of the drawing were scribbled out. His second bend angle was different to the first, as a result of the second set of parallel lines not being parallel to the first set.

Because he was "just looking for [his] angle", a **line** was constructed the same way as for the previous bend to calculate the measurement for the cut-out. David then hesitated and read the job sheet as he was "just making sure of [his] plan, so [he didn't] get anything wrong". The **diagonal offset** distance was measured. This distance was then transferred to the corresponding place on the downpipe; however, numerous probes to the value of this distance in the stimulated recall interview elicited that the **diagonal offset** was 150mm. The actual distance marked on the downpipe was greater than this value.

Once David had identified the centre line and marked it around the downpipe, his strategy appeared to become convoluted and confusing to him. He could identify which side to mark his V because "it's exactly the same, but it's back the other way … before I had to cut through the seam, not I have to cut through the other side". At this point, David had to identify the correct cut-out measurement, and in the stimulated recall interview, he stated:

> ...I'll go back to me angles to just make sure they're right and that – I already had it right but just checking and throwing some other sort of measurements in there to see what that looked like...
>
> *So what made you check it again?*
>
> I don't know. The angle that it come at, the degree, just make sure that I had it right.

Although he had constructed both angles to full size in the drawing, he re-arranged the set-squares in a 90° + 45° combination on the diagram as in Figure 7.9. In doing this he identified the angles verbally as "your 90 and your 30".

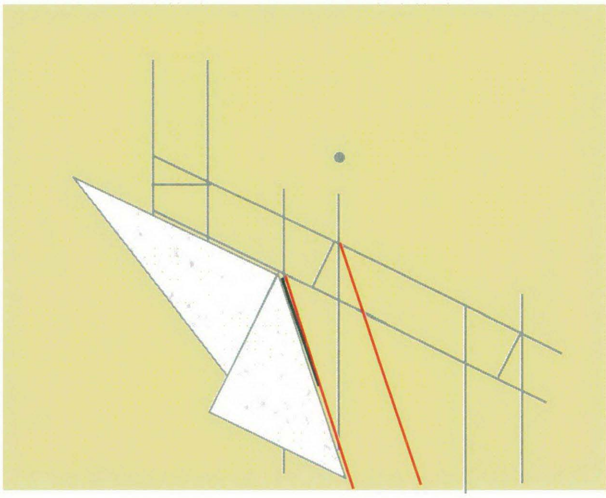

Figure 7.9. David: Re-checking second bend on drawing.

New "**verticals**" were drawn in using the downpipe as a template. During the next three minutes, there were numerous episodes of measuring various aspects of the drawing interspersed with periods of hesitation. The following transcript is an excerpt from these three minutes:

Can you tell me what you were thinking?

Just thinking that the other angle that I threw in then... what it was looking like if I had have done it sort of that way... but I had it done the first time when I marked there. I was just confusing myself there a bit.

The first time that you did by sight...

Sight and off the angle, yeah.

So what are you doing now?

Just the angle, the cut-out of the other one that I was thinking of, just making sure that it was right again.

And was it?

Yeah. To the other one, yeah.

You still don't look convinced there.

No. Just thinking that, that angle, I was sort of throwing myself off. I had it right the first time, I should have just went off that it would have saved a lot...

So what do you think caused this to be out so far.

The other one?

No, this one that you've just done, the second one.

Um... just the angles, I had them around the wrong sort of way as I went in to it, just confusing myself sort of thing.

But obviously there's something about the drawing that you're not convinced about.

Yeah. That, but the next angle actually, like, how I had it – when I went to draw the second drawing as I did after the first one, that's sort of put me of the whole track. I should have just went with me instinct sort of thing, with that first – because it was right. But I was just checking. It's just another form of working out, with checking and that sort of stuff.

But what angles have you got there?

That's a 90 and a 60 there, but as I was saying, it was just throwing myself off – I wasn't thinking right.

David then drew in the cut-out lines either side of the centre line using the measurements from his first bend "it was off the drawing – the measurements, they'd be the same sort of thing". He hesitated again "just thinking of another measurement that I could have done, another way but... then I've turned it over just to get another look at an angle, to see what it would come out like". He then turned over the paper and re-drew the first angle to full size again, "which was just another example of the angle that I already had. I was just checking if it was any easier to do it this way, but it sort of worked out around the same". This procedure seemed to make the situation clearer.

Eddie

Eddie's construction of the diagram to full size occurred in the Setup and Offset KPSs. The drawing he produced in the Setup KPS is provided in Figure 7.10.

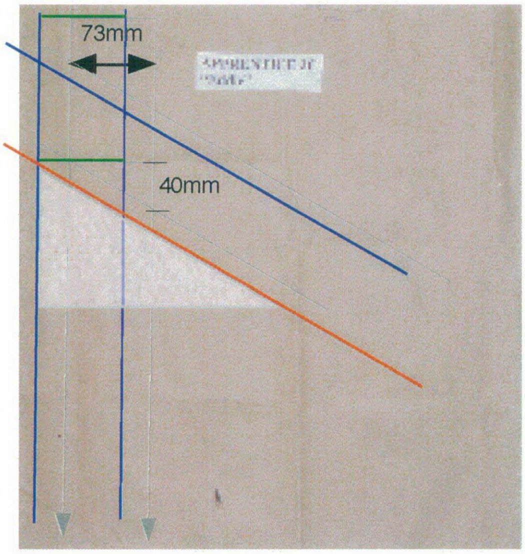

Figure 7.10. Eddie: Set-up drawing.

In this KPS, Eddie drew the first bend to full size only, beginning with drawing **parallel lines** using the downpipe as a template as he "just traced it like that [because it was] easier to do it without measuring it". Any **lines** on the drawing that needed to be perpendicular were constructed using a set-square. A mark was made 125mm from the top line "where the bend's going to go".

Eddie then used the 60° angle from the set-square to aid in the construction of the **diagonal offset line** because the "leftover would have made 120°". The cut-out measurement was derived in the same manner as Chris and David, and measured to be 41mm.

In order to calculate the offset distance in the Offset KPS, Eddie proceeded to draw the rest of the job to full size. He began by measuring 150mm out from the first set of verticals: "I moved it off the para … well, out square, at 90° … 150 out where the wall is …". Marks were made at two places (see Figure 7.11). The degree to which these marks were made perpendicular to the first set of verticals was done by visual estimation.

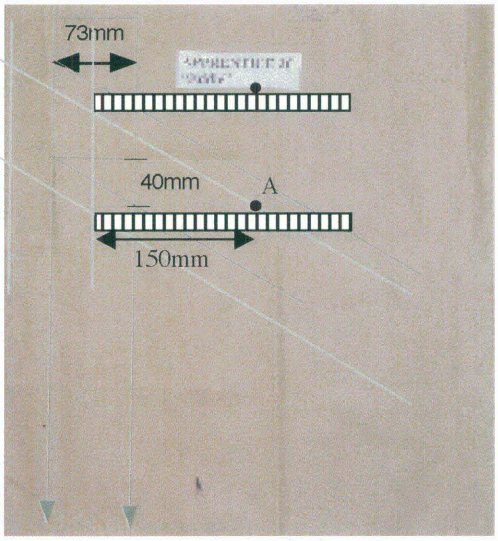

Figure 7.11. Eddie: Drawing the offset to full size.

The second mark for 150mm (point A) coincided with the diagonal line for the offset. The downpipe was then placed exactly on the drawing, and this mark at A transferred to the corresponding place on the downpipe because he "can sit it up there, then, and it's right to go". No measurements of this diagonal offset distance were taken, nor were the lines for the second bend constructed.

Fred

Fred was very precise when constructing his drawing, and drew the whole job to full size before beginning the fabrication process. His diagram is provided in Figure 7.12.

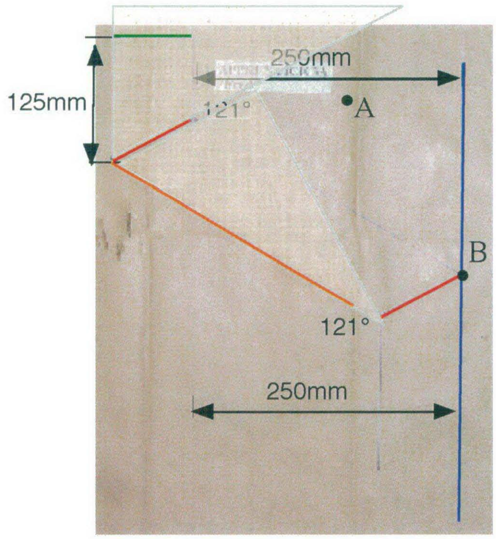

Figure 7.12. Fred: Set-up drawing.

Fred indicated at the beginning of the construction what he expected the final product to look like. Lines were constructed to the exact measurements indicated on the drawing with no "overshoot" of the line lengths, as can be seen in some of the other participants' drawings. Fred commented that he "didn't want thousands of lines going everywhere because it just gets confusing".

All sets of parallel lines indicating the downpipe width, were drawn by first marking two points the required distance from the first line, and ruling a line between them. Fred estimated the degree to which distances were perpendicular using visual estimation only, as opposed to using a set-square to provide a 90° angle.

Perpendicular construction **lines** required, such as the top of the downpipe, were drawn in using a set-square. There were periods of hesitation in using a 30/60/90 set-square to figure out how to generate the correct angle for the diagonal offset. Eventually, a **line** was drawn using the 60° angle of the set-square, as opposed to a combination adding to 120°. Following more hesitation, the **diagonal offset line** drawn in.

In the early period of this long derivation of the offset angle, Fred used a ruler to mark a point at 150mm to indicate the offset mark at A. After the angle was completed, this first mark was not used and a measurement of 250mm was then used for the offset mark at B. A **line** was drawn on the right hand side using the same methods used earlier for providing parallel lines. **Red lines** were constructed and measured a number of times. There was no evidence of a useable cut-out measurement being gained from this diagram.

Gerry

Gerry used a similar method for constructing the drawing to Fred. There was one notable addition of strategy, in that the perpendicular distances of both the downpipe width, and offset vertical lines, were aided with the use of a set-square to ensure such perpendicularity (see Figure 7.13).

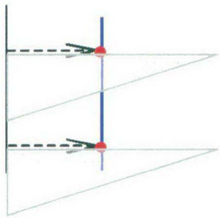

Figure 7.13. Constructing perpendicular lines.

The diagram produced by Gerry is shown in Figure 7.14.

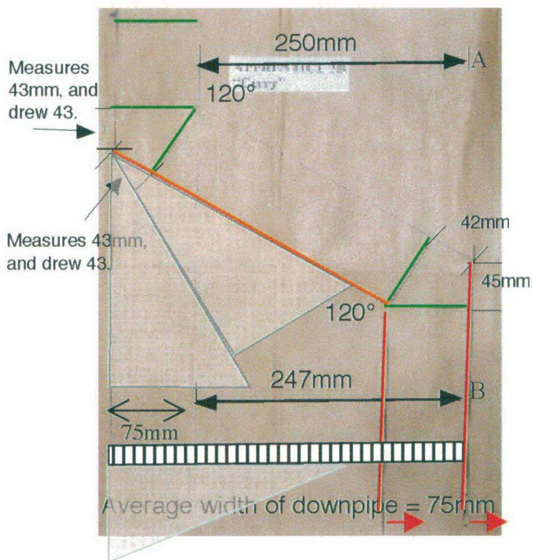

Figure 7.14. Gerry: Set-up drawing.

The set-square was also used to construct **lines** which needed to be perpendicular to other lines. In a similar manner to Fred, Gerry also took time to work out which combination of angles, and in which orientation, would give the required **diagonal offset line**. Eventually a combination of 30°+ 30° to "get 60° going down there ... or 120" was used to "mark it down an angle".

After completing the whole diagram to full size, a set-square was used to insert **perpendicular lines** to aid in the cut-out measurement. At the time, he did not appear certain which lines would give the required cut-out measurements. During the interview, Gerry stated that "they're normally both the same but you can draw both to check". After measuring all four of these lines numerous times, Gerry identified that the second bend measurements were not the same as each other, or the same as the first bend measurements. He then repeated two offset measurements at A and B. This resulted in a slight pivoting of the **second vertical lines** to the right. The green **lines** were again remeasured, although the resultant change in measurement values was negligible.

Howard

Howard constructed one bend during this Key Performance Stage. He used the downpipe as a template to generate sets of parallel lines of downpipe width on his drawing, and used combinations of the set-squares to generate the correct angle. The first attempt at deriving the angle resulted in using the 90°+60° angles in "just getting the 120° ... maybe 160°". A second attempt provided the combination used in the actual diagram, and 90°+30° angles.

A set-square was used to draw in **lines** in a similar manner to Chris, and was done so in order to "square it across to get the measurements to cut out". When asked where his drawing could help in the fabrication process, Howard stated that he needed this drawing so that he could get "the correct amount to cut out". At no stage did Howard attempt to draw more than one bend of the diagram, nor did he allow his drawing to be kept as data.

Descriptive analysis

All of the participants created some, or all, of the scale diagram to full size. The degree to which an individual participant completed the entire figure depicted on the job sheet varied. This variation ranged from drawing only the first bend, to including the diagonal offset lines, to drawing the entire downpipe. The participants' responses were organised into three groups based on this variation, with the group only drawing one bend provided first.

Group 1

Group 1 consisted of *Howard*. The response in this group consisted of only drawing one bend. Howard's rationale for this action was that only one bend was required to inform the fabrication; the remainder of the data would inform the job directly from the Job Sheet.

Group 2

Group 2 consisted of *Eddie*. The response in this group consisted of drawing more than one aspect of the diagram, but not to completion. Eddie drew the first bend to scale, and then produced the diagonal offset distance only in order to establish the point at which to begin his second bend. As with Howard, Eddie did not attempt to draw the entire second bend to full size. Eddie stated that the second bend was not required because the measurements would be same as on the first bend.

Group 3

Group 3 consisted of the remaining six participants: *David, Chris, Fred, Anthony, Gerry*, and *Bruce*. Responses in this group drew the whole diagram to full size. However, within this group, three sub-groups, A, B, and C can be formed based on similarities and differences across these performances. These sub-groups are outlined below in order of increasing competence, with sub-group 3A comprising the poorer performances.

Sub-group 3A contained *David, Fred* and *Gerry.* These three responses produced incorrect diagrams. Although complete, these drawings did not reflect the required specifications as set out in the job sheet.

David attempted to draw the whole diagram to full size, but his final drawing was not correct. Of all the participants, David had greatest difficulty in drawing the components that made up the entire diagram. Each section consisted of incorrect decisions, hesitation and confusion. Although his first bend was eventually produced, he did not appear sure of the process. Following the first bend, David drew the diagonal offset distance. This procedure was lengthy and also incorrect. The second bend was completed, but resulted in the second set of lines not being parallel to those drawn for the first bend. David spent time re-drawing the second bend, but in the end abandoned this component, turned the page over, and re-drew the first bend. Even though David drew the entire drawing to full size, he was not successful in all components, only adequately producing the first bend and diagonal offset distance.

Fred and Gerry produced similar responses. They drew their diagrams with a high degree of accuracy, particularly in drawing parallel lines of 75mm width using a ruler instead of the downpipe as a template. These drawings were not correct due to an incorrect offset distance. Fred initially marked 150mm on his paper, but concluded with 250mm as the offset distance; Gerry drew an incorrect offset distance in the first instance.

Sub-group 3B contained *Anthony.* This response resulted in the correct diagram, but performance was characterised by hesitation and convoluted actions to aid in completion.

Anthony also completed the full-size drawing, but had difficulty in establishing where the second set of parallel lines should be placed. In the fabrication of the second bend, Anthony recognised that he had made a mistake in his drawing, resulting in an incorrect offset distance. He subsequently corrected his diagram, eventually completing the full-size drawing correctly.

Sub-group 3C contained *Bruce* and *Chris*. These responses that produced correct diagrams of the whole downpipe, with diagrams where both angles were the same, and the correct offset distance of 150mm was used.

Chris completed his drawing in a procedural manner, and focused on precise measurements such as creating the parallel lines 75mm apart using a ruler. Each aspect was carefully drawn, resulting in both angles measuring 120° and the offset distance at 150mm.

Bruce completed the entire drawing to full size in a competent manner. He completed the first bend, then the offset, and then the second bend, without any hesitation or mistakes. He completed all parallel lines using a downpipe as a template.

Summary

By examining the descriptive vignettes of drawing a diagram to full size, three groups based on the degree of drawing completion were obtained. Table 7.1 provides an overview of these three groups.

Table 7.1. Degree of completion of full-size diagram

Group	Degree of completion	Participant
1	Draws the first bend only because that was all that was required.	Howard
2	Draws the first bend and diagonal offset lines because that was all that was required.	Eddie
3	First bend, diagonal offset lines, and second bend.	
3A	Incorrect drawing	David
		Fred
		Gerry
3B	Correct drawing following errors	Anthony
		Gerry
3C	Correct drawing	Bruce
		Chris

By using the criteria of drawing completion to underpin the descriptive analysis, the responses can be grouped. However, the degree of drawing completion does not necessarily provide insight into the 'quality' of the performance. For example, Howard is seen to have a 'lesser' performance than Chris because Chris produced more components of his drawing.

If only one bend was drawn, is such a response necessarily a lesser quality than a response where two bends are drawn? Such a question is intuitively easy to answer; however, if the reasons for each performance are examined, the quality of the cognition involved in these performances may provide greater insight into the performance.

Theoretical Perspective

This section considers the quality of responses by utilising the SOLO Model, and is divided into two parts. The first part presents a task analysis of the performance, leading to the expected SOLO levels for drawing a diagram to full size. In the second part, the descriptive vignettes are analysed for cognitive performance using the SOLO Model.

Task analysis and predicted SOLO descriptors

A task analysis of drawing a diagram to full scale to inform the fabrication of an offset downpipe was carried out following the Pilot Study. Initially, the participants consulted the Job Sheet to determine the specifications for the fabrication. All of the participants then chose to draw the diagram to some degree to enable a cut-out measurement to be taken. A sample drawing is provided in Figure 7.15.

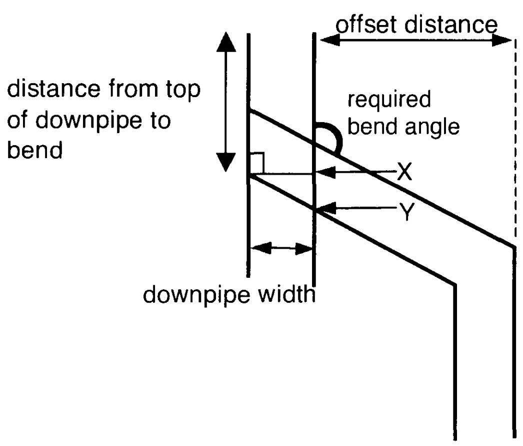

Figure 7.15. Task analysis drawing

To complete the task, the participants needed to utilise three concepts: draw the first bend, establish the offset distance, and then draw in the second bend. To make the first bend, there are a number of elements that need to be considered. These elements are the distance from the top of the downpipe to the bend, drawing parallel lines, and setting the required bend angle.

The second concept in drawing the diagram to full size is the establishment of the offset. This task requires the participant to consult the Job Sheet to determine the required offset distance. In correctly drawing the offset distance, the participant needed to measure from the right of the first set of parallel lines, to the right of the second set of parallel lines.

The third and final concept developed in order to draw the diagram to full size, involved drawing the second bend. Once the offset distance was marked on the drawing, the second bend can then be drawn. Elements required for completion of the second bend include drawing the first parallel line from the offset point and parallel to those used in the first bend, and placing the second parallel line to the left of the first parallel line. This method of construction does not utilise angle measurements, as if it is done correctly, the angle should be the same as the first.

There is an alternative process for drawing the second bend, which may use angle measurement. This process would consist of establishing a point on the diagonal offset lines such that it corresponded to the correct offset distance, constructing an angle of 120°, producing a line from this angle to make the bottom section of the downpipe, and drawing a line parallel and at the required distance to the left. of this line.

The previous chapter denoted the interpretation of Job Sheet specifications as existing in the concrete symbolic mode. Responses for drawing this diagram to full size are also for performance in this mode. Table 7.2 provides the detail of qualitative descriptors using the SOLO Model to describe cognitive performance of drawing an offset downpipe to full size in order to inform the fabrication of that downpipe.

Table 7.2. SOLO levels of hypothesised concrete symbolic responses

Level	Descriptor
Unistructural (U_1)	Focus on one element only. This element could be the construction of parallel lines, construction of perpendicular lines (top of downpipe), measurement from the top of downpipe to the bend, or the establishment of the bend angle itself.
Multistructural (M_1)	Elements that make up the bend are dealt with independently. Some of the elements outlined above may be combined in an attempt to produce the bend, but this process may contain confusion, hesitation, be incomplete, or contain misconceptions.
Relational (R_1)	Can complete the drawing of one bend, but this takes time due to the number of elements which need to be taken into account. Performance at this level can be stilted and lengthy, but ultimately lead to completion of the bend.
Unistructural (U_2)	Can draw one bend efficiently, taking all aspects into account. Performance starts to become automated and one bend becomes a new 'element' which can then be used in a larger task. Focus is clearly on this element and problems arise when attempts are made to incorporate it into the larger task.
Multistructural (M_2)	Draws the diagram to full size procedurally, but sees the components as unconnected. For example, the first vertical section is constructed as part of the first bend; the second vertical section is constructed as part of the second bend with no connection to making it parallel to the first. This may result in the bend angles being different. Elements making up this level may be missing or incorrect.
Relational (R_2)	Full-size drawing is completed competently. Connections between aspects are seen, such as once the diagonal offset distance is obtained, the second set of parallel lines may be constructed as parallel to the first, as opposed to being constructed from the angle of the second bend.

In proposing SOLO descriptors, it is also important to consider two possible cycles of levels. For drawing a diagram to full size, the first cycle deals with learning to draw one major aspect of the diagram, one bend, and the second cycle has as its focus, the incorporation of this concept into the larger problem of drawing the whole diagram to full size. The detailed descriptions of the SOLO levels above illustrate the possibility of a deeper interpretation of the groupings in the previous section.

Theoretical analysis

In this part, the SOLO Model is applied to the descriptive vignettes to provide a qualitative insight into the cognitive developmental aspect of each performance. The responses are presented in order of cognitive quality as determined by the task analysis above, beginning with David, whose response exhibited the lowest structural complexity.

David

David could construct one bend, and although there was some hesitation regarding whether this bend was accurate to specifications, this component was correct. David marked the offset distance of 150mm, and used this mark to draw the parallel line for the second set of verticals. He used visual estimation to establish the parallel line from this mark, but these lines were not parallel, and the line subsequently produced resulted in a second bend angle of 124° instead of the required 120°.

The remainder of the process contained incorrect assumptions and periods of hesitation. For example, he used the set-squares at a combination of 135° whilst stating that it was 120°, therefore producing incorrect parallel lines; he hesitated as a result, unable to reconcile that his assumed 120° had a pair of lines clearly not parallel to the first pair. Despite attempting the second bend, he did not complete it correctly. His final procedure was to turn the paper over and re-draw the first bend again on the back.

David drew the first bend to full size, and completed the offset. The second bend was attempted unsuccessfully, although this process did result in a complete diagram. Due to doubts regarding the accuracy of his drawing, David abandoned this drawing, with the first bend and diagonal offset distance re-drawn competently. David had accrued knowledge of two elements of the performance, namely the first bend, and the offset. These were applied in a procedural manner, and hence this response is coded as multistructural, M_2.

Fred

Fred produced the entire diagram to full size. All aspects were attempted with the rationale of producing a simple diagram with no additional lines. Fred was competent at drawing one bend to scale, and proceeded from there to establishing the offset distance. Although initially marked as 150mm, the offset distance used ended up as 250mm.

Apart from the offset distance being too large, this drawing was technically correct. Fred had accrued knowledge of two elements of the performance, namely, the first and second bends. In dealing with the second bend, Fred was unable to incorporate the correct offset distance. Therefore, this response is coded as multistructural, M_2.

Gerry

Gerry's performance was similar to that of Fred, producing the whole drawing to full size. Gerry drew the first bend competently, but his offset distance ended up being 250mm as opposed to the required 150mm.

The second set of diagonal lines were produced as a result of drawing the second bend. However, the fact that his offset distance was incorrect places the response as multistructural, M_2.

Anthony

Anthony drew the entire job to full size. He drew the first bend competently, using a protractor to establish the 120° angle of that bend. The diagonal offset distance was established, and the second set of parallel lines drawn from this mark using the downpipe as a template in conjunction with visual estimation of their parallel nature to the first set.

Anthony was able to form relationships between the first and second set of parallel lines, yet incorrectly derived the offset distance initially. Nevertheless, he was able to correct his error when relating this diagram to the requirements of the whole task. Hence, this response is coded as multistructural transitional, $M_2 \rightarrow R_2$.

Chris

Chris produced the whole diagram to full size. Each aspect of the diagram was produced using precise measurements as opposed to the downpipe as a template, resulting in a correct diagram.

The vertical lines for the second set of parallel lines were drawn so that they so that they would be parallel to the wall of the house. Therefore, Chris could relate these two elements of the drawing. The offset distance was also correct. Hence, this response is coded as relational, R_2.

Bruce

Bruce was quick and accurate in his construction of the whole diagram. His verbalisations consisted of a single statement that he was "going to draw up the diagram". Much of this process appeared automated, with each aspect of the diagram coming quickly after the previous one.

Bruce established the second set of vertical lines using the property of the parallel nature of them to the first set, and as such, his performance was similar to Chris and places this response as relational, R_2.

Eddie

Eddie competed one bend to full size, as well as the diagonal offset distance. He did not attempt to construct any further aspects of the drawing, such as the second bend. The first angle provided the cut-out measurement for both bends on the fabrication, and the diagonal offset mark was transferred directly from the drawing to the actual downpipe.

Eddie stated that what he had drawn was sufficient to inform the fabrication of his offset downpipe, hence no further aspects were of the diagram were needed. The factor of choice, as opposed to inability, is significant. Eddie drew fewer components because he was relating them not to each other, but to the larger problem to be solved. Being able to take into account a larger sphere of the problem, as opposed to only the constituent Key Performance Stage under examination, places this response above that of Bruce and Chris. Therefore, this response is coded as beyond relational, $R_2 \rightarrow$.

Howard

Howard only drew one bend to full size. He did not attempt any further elements of the diagram. As with Eddie, the reason no further aspects of the diagram were drawn was that Howard stated that it provided the measurement for the cut-out. This diagram was then not referred to for the reminder of the fabrication.

Howard only drew one element of the diagram, however, this was by choice. Howard used this Key Performance Stage to provide the minimum data necessary to inform the larger problem. Therefore, this response is coded as beyond relational, $R_2 \rightarrow$.

Synthesis

In summary, each of the performances of drawing a diagram to full size could be analysed using the SOLO Model. Each response was examined for its cognitive structure and can therefore be arranged in levels of increasing quality. The results of the theoretical analysis are provided in Table 7.3.

Table 7.3. Theoretical analysis of drawing diagrams to full size

Participant	SOLO Level
David	Multistructural (M_2)
Fred	Multistructural (M_2)
Gerry	Multistructural (M_2)
Anthony	Multistructural transitional ($M_2 \rightarrow R_2$)
Chris	Relational (R_2)
Bruce	Relational (R_2)
Eddie	Relational transitional ($R_2 \rightarrow$)
Howard	Relational transitional ($R_2 \rightarrow$)

All of the participants were able to complete at least one bend, resulting in second cycle responses. The proposed SOLO descriptors were sufficient in supporting the majority of response codings, however, there was evidence of transitional responses. These transitional responses occurred at $M_2 \rightarrow R_2$, as well as the identification of two responses beyond R_2 in the concrete symbolic mode.

David, Fred, and Gerry produced multistructural responses. Although these apprentices completed the whole diagram to full size, their diagrams contained inaccuracies. David was unable to incorporate the second bend correctly, whereas Fred and Gerry were unable to incorporate the correct offset distance.

Anthony produced a transitional response: $M_2 \rightarrow R_2$. His performance was initially similar in structure to Fred and Gerry, with the exception that he was able to self-correct to produce the correct drawing. Subsequently, Anthony produced an accurate full-size drawing that reflected the specifications as laid out on the job sheet.

The third group of responses were obtained from Chris and Bruce and were coded as R_2. These performances were similar to those in the previous group, in that the vertical lines for the second bend were made parallel to the first. However, Chris and Bruce were also able to correctly incorporate all the elements required to produce a technically correct full-size diagram.

The highest responses were those of Eddie and Howard. The distinct difference between these two responses and the other apprentices, is heavily tied to the rationale underpinning performance. The rationale utilised by both Howard and Eddie was that not all the diagram was necessary to inform the larger task.

Whilst performing the Key Performance Stage of drawing a diagram to full size, Howard and Eddie could also hold the requirements of the whole task as the ultimate goal. This was a distinct difference between these two participants and the other cohort, and resulted in a coding necessitating recognition of higher quality than that of Bruce and Chris. The coding for both Howard and Eddie is represented as beyond relational in the concrete symbolic mode ($R_2 \rightarrow$).

Conclusion

The utilisation of a stimulated recall technique was effective in enabling verbalisations of participant thoughts in drawing a diagram to full size. In conjunction with the video data obtained of the performances, these verbalisations allowed insight into the cognitive behaviour of apprentices in this aspect of the whole task. By providing the participants with an opportunity to talk through the thoughts they were having during this activity, a clearer picture of how they constructed their drawing was obtained, as well as the degree to which this drawing informed the larger task.

It would appear that for independent tasks, such as drawing the diagram to full size, that the SOLO Model was useful in providing a cognitive perspective to the performance. This is particularly evident when considering tasks within the concrete symbolic mode, such as technical drawing in this case. Previous studies incorporating the SOLO Model to provide a cognitive developmental perspective have largely focused on functioning in this mode, as it is where formal schooling takes place and performance of mathematical tasks is predominantly decontextualised.

The SOLO Model was able to describe the performances for participants who had partitioned drawing the diagram from the larger task of fabricating an offset downpipe. However, the responses exhibited by Eddie and Howard indicated that they were mindful of the whole task *during* this drawing process. The performances of Eddie and Howard may have been different if their only task was to draw the diagram to full size without having to take into account its role in a larger problem. The fact that they chose not do draw the diagram in its entirety should be taken in context. As drawing the diagram to full size was a component of the entire task, it was important to acknowledge the distinction being choosing to draw elements versus the ability to draw elements. The degree to which they completed their diagram to full size was dependent upon the level of its use in the overall task. Ultimately, more data are required to inform the SOLO Model when dealing with coding *aspects* of larger tasks, as isolated events.

CHAPTER 8

CONCLUSION

This chapter considers the overall findings of the study, in which the structures of mathematical skills and knowledge involved in vocationally oriented contexts were investigated from a cognitive developmental perspective. Initially, limitations imposed on the design of the study are discussed. An overview of the results in the light of the two research questions addressed in Chapters 6 and 7 are presented. This is followed by a consideration of the implications of the findings in relation to the field of mathematics in the workplace and the SOLO Model. Finally, a number of future directions are proposed as a consequence of the findings of the study.

Possible Limitations of the Study

The results described in the preceding chapters must be viewed in the light of possible limitations that arose during the course of the research. This section reviews four potential limitations. These are the homogeneity of the research sample, the schooling background of the participants, the size of the sample, and the categorisation of participants' responses using the SOLO Model.

The first limitation relates to the potential homogeneity of the sample. All participants were male, of a similar age, and were undertaking formal training at the same institution meaning that they would most probably have been taught similar techniques to solve problems. This may have resulted in predisposition towards particular solution paths and understandings.

However, this was not considered to be a major factor given that none of the participants involved in the study worked for the same plumbing firm, and therefore came with differing workplace experiences. Additionally, not all of these apprentices worked in the Orange area, with many travelling from outlying regions, up to four hours away.

In considering this limitation, it is also appropriate to consider the nature of learning in the apprenticeship model. Whilst the participants in this study attend the same formal learning institution, the time spent in this context was small when compared to the time spent with their employer. Although the Technical and Further Education college was where some fundamental skills were learned and knowledge taught, the workplace was where the problems were solved and the preferred manner of solution dictated by the employer. As such, each workplace may have differing practices for completing the same task.

Therefore, even though the apprentices in the sample carried out their formal training in Orange at the time of the data collection, there was a broad diversity of participants' workplace backgrounds present. Nevertheless, it is important to point out that the objective of the research was not to obtain population norms but to identify aspects of developmental cognition using the SOLO Model.

The second limitation relates to the schooling background of the sample. It is likely that the formal schooling (up to age 16) required in Australia may be an influencing factor in the responses obtained. Studies such as de Aguero (2003) considered how tradesmen performed their jobs within the developing world and involved tradesmen with little or no formal schooling. Her studies showed that these workers solved tasks in an efficient, accurate and expert manner in the absence of what could be considered academic mathematics. Consequently, it could also be expected that tradesmen with little or no formal schooling would also be able to fabricate offset downpipes.

Therefore, it is important to acknowledge that formal schooling experiences may affect cognitive performance in workplace tasks, and therefore the findings of this study might not be generalisable to populations with different backgrounds. Future research may explore both the differences in cognitive structure of responses in developed and developing nations, as well as the impact of formal schooling in mathematics on the solution paths chosen in vocational contexts.

The third limitation relates to the size of the sample. Previous research using the SOLO Model utilised a larger sample size than the present study to validate SOLO levels. When considering the constraints on time of a Masters' research program, and the lengthy and qualitative nature of the data, a larger sample was not possible within the context of the study. From the perspective of the TAFE college, issues also arose concerning sample size. Withdrawal of multiple participants was restricted, due to time required for data collection, and impacts on the learning opportunities missed within the normal teaching and learning program. Nonetheless, for the exploratory purposes of this research, there was a sufficient number in the sample given that the TAFE teachers attempted to provide a range of differing abilities within the sample, as evidenced by the spread obtained using the SOLO analysis.

However, exceptions to this arose in Chapter 7 with coding the responses of the two students: Eddie and Howard; cognitive structure was not easily codable past R_2 in the concrete symbolic mode. As these types of responses were not expected, it would have been difficult to allow for a purposeful sampling involving a larger number to include more responses of this type. Nonetheless, the sample size was sufficient in this study to enable the research questions to be addressed and form a sound basis for future research.

The fourth limitation arose during the analysis phase, and concerns the establishment of the SOLO descriptors. The underlying rationale for this research was to assess the validity of the SOLO Model in providing a cognitive developmental aspect to workplace or practical tasks. Of concern was that the SOLO descriptors would be reliable.

Prior to this study, the researcher had undertaken analysis of a considerable number of tasks over a number of years, using the SOLO Model to obtain cognitive developmental pathways of mathematical understanding within formal schooling concepts. Therefore, the researcher was already practised using the Model. Within the present exploratory study, scripts were examined and initial descriptors for the levels derived. Subsequent coding was carried out in a cyclical manner, until congruence of descriptors and coding between the researcher and a co-researcher were obtained. The co-researcher was experienced in the use of the SOLO Model, having supervised numerous post-graduate studies in this area, as well as having published numerous papers on the Model. Using these agreed-upon descriptors, qualitative judgements on apprentice's performance could be obtained. The descriptors, along with a selection of scripts were then given to a third independent researcher experienced in the use of the Model. The result of this independent analysis was agreement with the two previous researchers.

Overall, despite the possible limitations imposed on the study by the nature of the sample and researcher bias, this discussion demonstrates that the effects of these factors on the results were considered carefully. In essence, the design of this study allowed for collection of detailed qualitative data in regards to apprentices understandings of the fabrication of an offset downpipe.

Synthesis and Overview of the Results

This section is divided into two parts. The first part considers the SOLO perspective on both tasks, and the completion of the SOLO coding. The second part explores a common theme evident in the fabrication of the downpipe and the drawing activity.

Synthesis of results

The research was explored in the environment of a TAFE college in a rural setting, with plumbing apprentices. These apprentices were employed by a variety of firms of different sizes and specialisations, and worked in towns of different sizes (populations ranging from a few hundred to approximately 35 000) in the surrounding area. These students were purposefully sampled to include a range of abilities and from each of the three years of study.

The context of the exploration of cognitive functioning was a practical task involving fabrication of an offset downpipe, using the specifications provided on a job sheet, and the materials supplied. Formal instruction in this task occurred within first-year plumbing courses, as well as being typical in many rural workplace contexts. However, despite being identified as a characteristic skill for plumbers to execute, proficiency in such a skill largely depended upon repetition in workplace contexts in the years following initial instruction. It is noteworthy to add that it is common for many modern houses to consist of offset downpipes fabricated from a variety of pre-formed bend angles. In these cases the plumber's role is simply to glue the fabricated parts together.

Drawing the diagram to full size was a tool used by the apprentices to provide measurements necessary in the fabrication. As such, this drawing was a component of the whole task. Apart from the specifications on the job sheet, the minimum data required to complete the task was the cut-out measurement from the first bend on the diagram to full size.

Participants responding at a higher cognitive level were able to incorporate the minimum conditions necessary to complete the task, and consequently were more efficient in their fabrication. In terms of improving overall performance on the task, efficiency of the performances of all of these apprentices could have been enhanced through reducing their reliance on measurements taken from the diagram, as drawing used time that could have been spent in fabrication. This situation was compounded for participants who drew diagrams where not all data were used.

Overall, these results suggest that the SOLO Model can be used to describe both workplace practice and tasks involving mathematical elements. A summary of the results are provided in Table 8.1, with participants ordered hierarchically for their cognitive performance on the whole task and in terms of drawing the diagram to facilitate fabrication.

Table 8.1. Overview of results using the SOLO Model

Concrete symbolic mode	**R_1**	**→**	**U_2**	**→**	**M_2**	**→**	**R_2**	**Beyond R_2**
Whole task	David		Anthony	Fred	Gerry	Bruce	Eddie	
					Chris	Howard		
Full-size diagram to facilitate fabrication					David	Anthony	Chris	Howard
					Fred		Bruce	Eddie
					Gerry			

'→' represents transitional responses between levels

All of the participants worked at a higher cognitive level for the diagram than for the task as a whole. This result can be explained by considering the working memory demands inherent in the problem-solving task.

In fabricating an offset downpipe, there are numerous aspects that need to be considered. These may include professional content knowledge such as direction of water flow, skills-based knowledge such as appropriate usage of tools, and mathematical knowledge such as keeping the product square or parallel and taking appropriate information from the diagram. Being able to consider all such aspects in order to complete the task uses significant working memory, particularly in novice tradesmen.

Drawing a diagram to full size can be considered to be one aspect of the whole task. By partitioning this aspect from the task, the apprentices significantly decrease the working memory demands compared to those required on a holistic level. Higher cognitive performance in the drawing activity can therefore be explained by such a reduction in working memory demands.

However, Howard and Eddie did not partition the drawing of the diagram to full size, but retained at least a peripheral connection of this activity to the whole task. They were therefore able to make judgements minimising the effort required on drawing so as to still inform the task.

Underlying mathematical theme

A mathematical concept underpins both the whole task performance and the drawing of the diagram to full size, namely, *angles in parallel lines cut by a transversal* (see Figure 8.1).

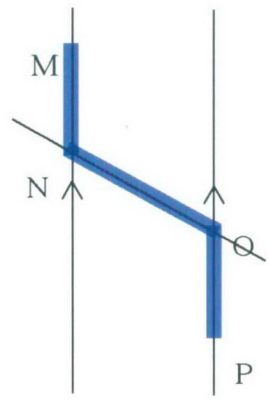

Figure 8.1. Parallel lines cut by a transversal.

The downpipe component can be envisaged by the blue overlay. For the downpipe to be effective, $M\hat{N}O = N\hat{O}P$, or conversely, $MN \parallel OP$. This relates to the geometrical theorem that states if and only if the two parallel lines are cut by a transversal, the alternate angles formed are equal.

Performance of the whole task, in particular efficient strategy use, were of higher quality where participants recognised that the bends on the downpipe had to be the same; a similar thought process supported the drawing of the diagrams to full size.

From the participants' perspective, explication of formal knowledge of the theorem was not necessary to complete the task. For competent performance, knowledge that the angles had to be the same for the downpipe to work was the most important fact. For those apprentices performing at a higher cognitive level, they were able to appreciate the dual nature of the geometrical theorem. However, they expressed this in more practical terms, namely, if the angles were the same, then the downpipe would fit into the gutter, and sit flat against the wall. If the angles were not equal, then the downpipe would not sit flat against the wall.

Summary

In summary, being able to draw the whole diagram to full size was not a necessary component of the fabrication. In the present study, drawing the diagram was a component of the larger task, and those apprentices who performed at a higher cognitive level recognised it as such, in particular, being able to think about the requirements of the larger task whilst performing component elements.

Overall, these results suggest that workplace performance can be examined using the SOLO Model. In the present case, drawing diagrams to full size comprised the focus of the investigation into the applicability of the SOLO Model in examining aspects of performance containing mathematics. Although this examination did not include every instance of mathematics observed within the whole task, it showed the potential of the model to provide insight into the cognitive functioning evident in tasks containing mathematics.

The results contained in Chapters 6 and 7 evidenced an underlying mathematical theorem supporting the fabrication of the offset downpipe. A thorough understanding of an underpinning mathematical theorem did not appear to be a necessary requirement for satisfactory workplace performance. However, the results suggest that the higher the structure of such knowledge, the more sophisticated the level of cognitive performance on the workplace task for the apprentice. Additionally, the ability to work with necessary and sufficient conditions, possibly as a result of such knowledge, led to improved performance on the workplace task.

Of note was the identification of an underlying mathematical concept for the task, that a transversal creates equal alternate angles in parallel lines. The ranking of responses using a rudimentary coding of this concept produced reasonably congruent results to those gained in the more rigorous analysis. Although it is not valid within the present study to draw conclusions between the role of the practical performance of fabricating an offset downpipe and the mathematical concept, there is some basis to investigate this connection further.

The underlying promise shown by the SOLO Model to examine both the mathematical concept and the workplace practice is motivating. In particular, the studies investigating the differences between mathematics in school and mathematics in work would benefit from a common theory and language by which to examine the similarities and differences inherent in these two environments.

Implications for Theory

In the present study, the SOLO Model provided the theoretical basis for the investigation into mathematics in work. This addressed one of the deficiencies of current research into the field, where a cognitive developmental perspective has been identified as necessary to inform actual learning processes (Sträßer, 2001). As a result of using the SOLO Model in this context, deeper insights into aspects of the framework as well as workplace practice can be gained.

The SOLO Model provided an avenue by which performance of the practical task could be investigated. The way in which the model could examine both observed and verbalised practice was a powerful tool, and provided insights into the cognitions of the participants. With the SOLO Model, the focus is on the structure of the response, therefore allowing different forms of practice to be considered, and fundamental cognitive structures to be determined. As each workplace context differs, so too do the potential differences in solution. The strength of the SOLO Model is that it provides a framework for the underlying cognitions, and hence, whilst the manner of solution for certain performances might differ, commonality in cognitive structure can be determined.

Previous research using the SOLO Model have been able to identify developmental pathways of students' understandings, and as such, have proved influential in improving teaching and learning experiences. Within the literature of the SOLO

Model, there is acknowledgement of the diversity of previous learning experiences that influence the acquisition of knowledge. It's strength lies in identifying the underlying cognitive structure whilst dealing with a wide variety of experiences brought to the analysis episode.

The potential of the SOLO Model in informing teaching and learning episodes within the apprenticeship model of training is evident. The cohort within the present study all came from different workplaces, each apprentice encountering diverse influences in their learning. In the TAFE context, the SOLO Model provides the possibility of identifying the fundamental components required for skill acquisition, irrespective of the external influences brought to the college be each individual.

However, socio-cultural studies of mathematics in the workplace have identified the importance of influences such as the environment, peers, mentors, artefacts, on the quality of the learning experience for workers. The quantity and richness of these studies gives a strong foundation for providing appropriate activities to support the developmental stages identified to underpin the acquisition of the appropriate cognitive structures necessary for the skill required.

As with previous research using the SOLO Model (see, for example, Panizzon & Pegg, 1997), results in this study suggest that there is a developmental pathway evident in the learning episode, and hence the cognitive steps moved through in learning the skill of fabricating an offset downpipe under the conditions set out in this research. However, the lack of a longitudinal design, in conjunction with the small number of participants, prohibits such a determination. Nevertheless, it is satisfactory to note that the SOLO Model can be used to describe performance of individuals; extrapolating that to a pathway that may be used to guide learning promises to be a substantial future direction.

The results showed predominantly concrete symbolic operation for the focus of performance in the overall task, as well as for drawing the diagram to full size. For both these analyses, the underlying requirement was to follow specifications on the job sheet. This constraint may have predisposed the cognitive performance to the concrete symbolic mode, yet if the task was oriented within the actual workplace, the cognitive requirements may have produced different results.

Generally, responses are coded at the highest level of structural complexity: For instance, a response containing ikonic and concrete symbolic elements is coded within the concrete symbolic mode. This precedent has been followed within this thesis. Whilst this process has resulted in attributing a level of cognitive operation to each response, the full nature of the performance was therefore not reflected. In particular, whilst a determination of concrete symbolic may have been provided to a response, the degree to which ikonic or sensori-motor thought supported the performance is not evident within a coding, of for example, M_2.

The predominance of research using the SOLO Model has involved functioning in the concrete symbolic mode. Hence, clear descriptors are available for levels of cognitive performance, making the identification of similar characteristics in different contexts relatively easy. However, research into functioning at the sensori-motor and ikonic modes is sparse. Whilst the identification of modal functioning is relatively easy, further detail into levels and cycles of levels within these modes remains elusive. The lack of a framework to identify these characteristics within the present data would result in a deep and thorough analysis, which is not within the scope of this thesis. Nevertheless, some addition to theory regarding these modes within practical workplace oriented tasks is possible.

Implications for Teaching

As a result of this exploratory study, a number of potential implications for teaching the fabrication of downpipes have been identified. Firstly, in terms of the whole task, identification of efficient strategies for task completion is an important element in minimising time and therefore maximising monetary gain in the workplace. Secondly, whilst competence in technical drawing is an advantage in drawing diagrams to full size, the ability to determine how this sub-task relates to the whole task may determine the degree to which the drawing is completed. This second aspect is closely related to the completion of the whole task.

The SOLO levels determined for the present task are yet to be validated longitudinally in future research, however, recent studies using the SOLO Model (e.g., Panizzon, 1999; Serow, 2002) have verified SOLO levels as cognitive developmental pathways in science and mathematics using longitudinal studies. It is therefore realistic to predict that the levels derived within the present study would be a powerful teaching tool should they prove to be a developmental pathway of cognition for this task. Once students could be identified as responding at a particular level, instruction could be given by the teacher to assist the student to reach the next level. In terms of formative assessment, such information would be an influential teaching and learning tool within contexts within a TAFE setting.

This discussion, although brief, highlights the central role played in acquisition of workplace learning of the teacher and workplace mentor. Studies of workplace learning support the important role played by the teacher and mentor in enabling their apprentices to learn the skills required to carry out workplace tasks. Knowledge of a cognitive developmental nature would enable the teacher to identify levels of understanding and subsequently devise activities to assist in the progression to the next level.

Future Directions

As the premise of this thesis was to explore novel aspects of both workplace mathematics and the SOLO Model, it is not unexpected that potentially fruitful research directions have arisen. Numerous avenues for further investigations have presented themselves, ranging from those associated with the intricacies of the present task of fabricating an offset downpipe, to more global directions relating to either the SOLO Model or exploring workplace studies from the perspective of developmental cognition. However, five areas stand out.

First, the method employed within this study resulted in an extensive rich data set. As such, not all directions were explored given the scope of this thesis. Closer examination of the existing data could investigate the role of multi-modal functioning as well as analysis of the remainder of mathematical elements, including the degree to which knowledge of parallel lines and a transversal related to cognitive performance already identified. Such an analysis would provide a more meaningful appraisal of the overall cognitive aspects of both the whole task, and the individual performance. Notwithstanding, there is also potential to explore the data from a socio-cultural perspective, and investigate the interplay between these data and that emanating from the developmental paradigm.

The second area for research relates to the SOLO Model and its potential to describe professional practice involving mathematics. This research direction evolved out of Chapter 7, and reflects the difficulties in determining appropriate coding for the two participants who were operating beyond R_2 in the concrete symbolic mode. This aspect relates in part to the drawing forming part of the larger task, and the responses of these two participants was a reflection of their ability to integrate this component into the larger problem. Further insight could be gained by investigating similar responses so as to determine similarities and differences.

Third, and associated with the present task but extrapolating also to the larger field, is the recognition that drawing the diagram to full size was only one element of the whole performance. Future studies may explore the differences in performance of individual component tasks, versus how these components are operationalised when included in a larger question. Such a study would inform cognition within problem solving contexts, and also teaching and learning episodes where often it is necessary to teach component elements, and reconstitute these back into the whole in order to solve an overall problem.

The fourth area regards incorporation of longitudinal design within the method would add to the knowledge of developmental pathways for this task, hence appropriately informing teaching and learning episodes. Such an element of design would alter the focus from analysing group responses towards individual routes of knowledge acquisition. Comparison of individual pathways could therefore determine the existence of universal pathways of cognitive development for this particular task. Such research could shed light on characteristics of cognitive development in workplace contexts.

The final possible area for research relates to the use of cognitive developmental theory in the wider area of mathematics for work. The premise of this thesis was to investigate whether developmental cognition was useful in analysing workplace mathematical practice. Whilst this research does not purport the superiority of a cognitive developmental perspective to providing insight into mathematics in work, it does have potential to provide a balance to the predominant socio-cultural studies that have dominated the literature.

Conclusion

Overall, this study has a qualitative perspective, and was designed to explore the feasibility of the SOLO Model to provide insight into cognitive functioning on workplace related tasks. The lack of a cognitive perspective in the research on mathematics in the workplace, led to analysing vocational mathematics using the SOLO Model. However, empirical evidence regarding the applicability of the SOLO model to workplace contexts was also absent from the literature. Hence, it was expected that a study of this kind would raise questions.

If further studies validate the SOLO Model in making sense of workplace mathematical practice, by association, the developmental cognitive paradigm also has potential to inform knowledge of mathematics in the workplace. Since the start of the present study, another research initiative has also been reported as attempting to also provide insight from the developmental perspective. Martin, LaCroix, and Fownes (2005) investigated plumber's understandings of fractions using a theorem developed by Pirie and Kieren (1994) to explain the mathematical learning process.

Not only was this study novel in exploring workplace mathematics from the perspective of developmental cognition, the cognitive theory chosen for its ability to describe the development of mathematical knowledge in formal schooling contexts had not been used to examine workplace mathematical practice.

Previous research has validated the model in supporting teaching and learning in formal schooling. This precedent, in conjunction with the promise shown here, indicates that it may be possible that knowledge of the cognitive developmental perspective in workplace practice could enhance the teaching and learning experiences in training for mathematics in and for work.

Therefore, it appears that a valid future direction is to further investigate cognitive developmental aspects the acquisition of mathematical knowledge in workplace contexts. In undertaking this work, socio-cultural perspectives should also be consulted and incorporated. It is hypothesised that the best position to inform teaching and learning of mathematics in and for work would entail a more imaginative juxtaposition of both socio-cultural and developmental ideas.

Post-script

The following publications have been based on elements of this research:

Inglis, M. (2004). "I said I taught the horse to sing: I didn't say it learnt": Issues underlying appropriate training for vocational uses of mathematics – Plenary Lecture. In. E. Lindberg (Ed.). *Proceedings of the 11th International Conference on Adults Learning Mathematics, Kungälv, Sweden* (pp. 28-41). Sweden: Göteborg University.

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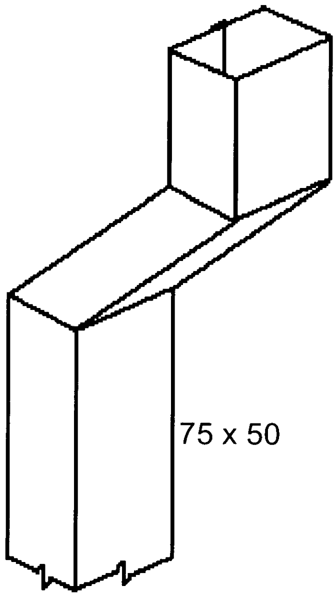
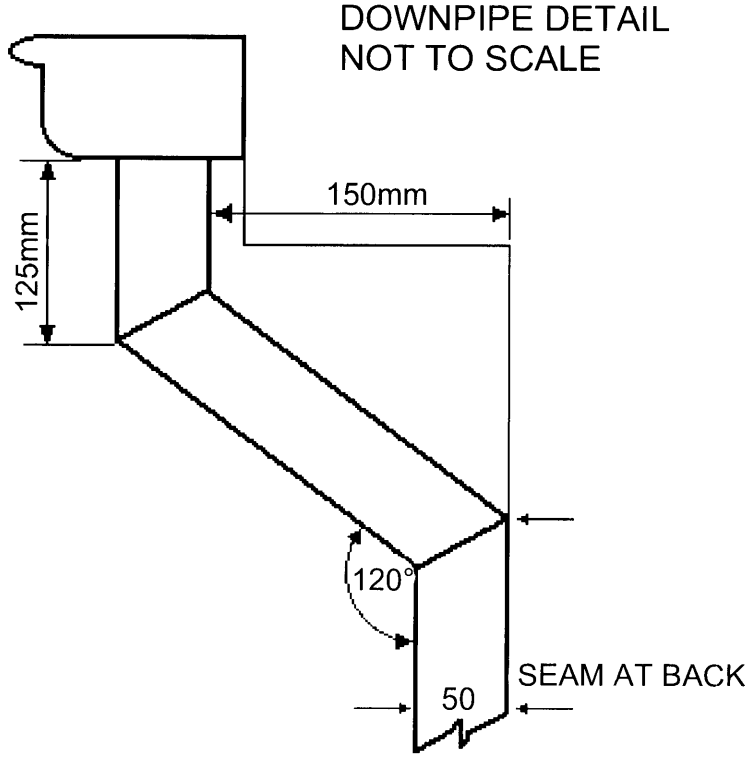
APPENDICES

A: Job Sheet for Pilot Study

Fabrication of a 75 x 50 rectangular offset downpipe.





B: Pilot Study Data Collection Protocol

Set-up requirements and equipment

1. One [1] length of 75mm x 50mm rectangular section gal downpipe
2. A selection of tools for fabrication: two set-squares (with angles of 30°, 45°, 60° and 90°), tin snips, hacksaw, hammer, pencil, permanent black marker, ruler, rivets, rivet gun, bevel, square, chisel
3. One [1] large sheet of butcher's paper
4. Power-point for video-camera power source
5. Large workbench for participant to make the downpipe

Pre-task reminders for researcher

1. Establish a relaxed, friendly and supportive atmosphere prior to and during the interviews
2. Gain the confidence of the participant by being open and frank about the purposes of the research
    - Do not mention that the goals are mathematics.
    - Discuss the purposes of the research as that you want to find out more about how plumbing apprentices execute a task and what they think as they do it.
3. Assume a respectful disposition towards the participant and the self-report data; communicate to the participant that they are being taken seriously.
4. Set up the video camera recording
    - Ensure that the video camera is set up to record the performance, and as much as possible reflect the line of sight of the participant.
    - Let the participant view through the view-finder so that they are aware of the range of the camera.
    - Ensure that the participant is comfortable with the scope of the picture.

Disclosure to participant regarding the data-collection and set up of the task.

1. Tell the participant what is going to happen, and set up the task:

    Your task is to make an offset downpipe from the job sheet provided. Your performance will be videoed using that camera. Use any equipment that you need to complete the task – you do not have to *put silicon on the joint. At the end of the task, we will go into another room and watch the video. You will then be asked to recall as accurately as you can, what you were thinking when you were making the downpipe.*

Post-task and pre-interview protocol

1. Re-state to the participant, issues pertaining to confidentiality of the data.
2. State expectations of the stimulated recall interview:

   I would like you to watch the video, and as much as possible recall as accurately as you can what you were thinking at that particular stage of the fabrication. There may be different things that you think about: the first one is thoughts you actually had at the time, and the second type may be things that just came to you as you were watching the tape, or you may like to explain what you are doing. All of this information is really important, but I am most interested in the thoughts you had at the time. You can stop the tape as often as you want if you need more time to think.

During-interview protocol

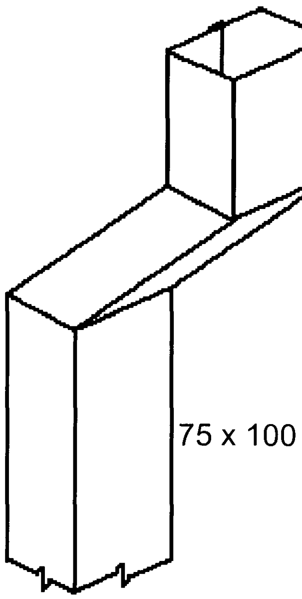
1. Avoid making interpretations of, and judgements about, what appears on the video tape or what the participant says.
2. Encourage and facilitate self-discovery; it is important for the participant to believe that they are capable of telling about mental processes.
3. Encourage the participant to talk; don't take over.
4. Try not to distract the participant from their main task of telling.
5. Keep the discussion focussed on the video session only. For this particular task, being highly contextual, some external factors may appear as being important to the participant although not related directly to the video.
6. Ask questions which invite open-ended recall, clarification and/or elaboration (i.e., "Were you having any thoughts at this time?").
7. Avoid leading questions or questioning techniques.
8. Keep checking the status is the self-report data.

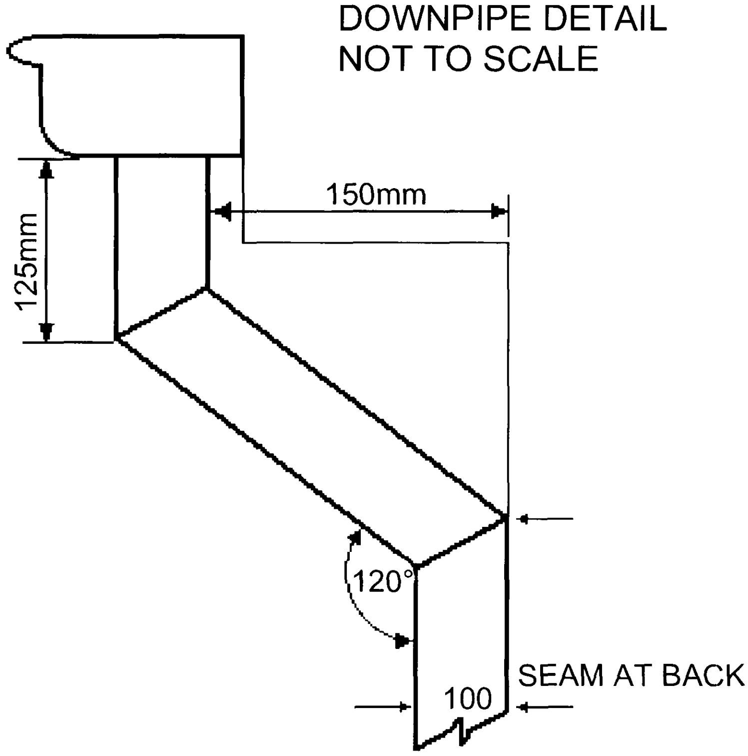
Post-interview session

1. Thank the participant for their assistance and that it was valuable.

C: Job Sheet for Main Study

Fabrication of a 75 x 100 rectangular offset downpipe.





D: Main Study Data Collection protocol

Set-up requirements and equipment

1. Separate work station for downpipe fabrication, preferably a separate room.
2. Large workbench for participant to make the downpipe
3. One [1] length of 100mm x 75mm rectangular section gal downpipe
4. A selection of tools for fabrication: two set-squares (with angles of 30°, 45°, 60° and 90°), tin snips, hacksaw, hammer, pencil, permanent black marker, ruler, rivets, rivet gun, bevel, square, chisel
5. One [1] large sheet of butcher's paper
6. Power-point for video-camera power source

Pre-task reminders for researcher

1. Establish a relaxed, friendly and supportive atmosphere prior to and during the interviews. As much as possible, set up the video well before the individual data collection so that the presence of the video camera is not novel. Spend as much time as possible before hand with the class prior to data collection.
2. Gain the confidence of the potential participants by being open and frank about the purposes of the research
    - Do not mention that the goals are mathematics.
    - Discuss the purposes of the research as that you want to find out more about how plumbing apprentices execute a task and what they think as they do it.
3. Assume a respectful disposition towards the participant and the self-report data; communicate to the participant that they are being taken seriously.
4. Set up the video camera recording
    - Ensure that the video camera is set up directly opposite the work area
    - Let the participant view through the view-finder so that they are aware of the range of the camera.
    - Ensure that the participant is comfortable with the scope of the picture.
    - Show the participant how to turn off the camera on completion of the task.

Disclosure to participant regarding the data-collection and set up of the task.

1. Tell the participant what is going to happen, and set up the task:

   It is a rainy day and there is no work to do outside. Your boss has left you in the shed to make up some downpipes for a job to save time. He has been out to the job site and taken measurements from the existing downpipes so that the ones you make will be the same. He has left you this job sheet. Your task is to make this offset downpipe to these specifications. You can complete the task using any way you like. At the end of the task, turn off the camera. We will go into another room and watch the video. You will then be asked to recall as accurately as you can, what you were thinking when you were making the downpipe.

Post-task and pre-interview protocol

1. Re-state to the participant, issues pertaining to confidentiality of the data.

2. State expectations of the stimulated recall interview:

   I would like you to watch the video, and as much as possible recall as accurately as you can what you were thinking at that particular stage of the fabrication. There may be different things that you think about: the first one is thoughts you actually had at the time, and the second type may be things that just came to you as you were watching the tape, or you may like to explain what you are doing. All of this information is really important, but I am most interested in the thoughts you had at the time. You can stop the tape as often as you want if you need more time to think.

During-interview protocol

1. Avoid making interpretations of, and judgements about, what appears on the video tape or what the participant says.
2. Encourage and facilitate self-discovery; it is important for the participant to believe that they are capable of telling about mental processes.
3. Encourage the participant to talk; don't take over.
4. Try not to distract the participant from their main task of telling.
5. Keep the discussion focussed on the video session only. For this particular task, being highly contextual, some external factors may appear as being important to the participant although not related directly to the video.

6. Ask questions which invite open-ended recall, clarification and/or elaboration (i.e., "Were you having any thoughts at this time?").
7. Avoid leading questions or questioning techniques.
8. Keep checking the status is the self-report data.
9. Keep an eye on Key Performance Stages and participant responses. Use the table below to maintain consistency in what to ask for further clarification for in the semi-structured interview session after the formal interviews. Do not ask these questions in the SR interview sessions so as not to bias the responses.

KPS + common procedure	Possible points for reflection
Setup	• How does the participant construct the scale drawing • What is their reasons for how and what they draw • How does the participant use the scale drawing to inform the task.
First bend • Measure the distance from the top • Mark the centre line • Determine which is the back of the downpipe – which direction for the V • Measure the deviation from the centre line to the top of the V • Draw the section to cut out • Draw the laps • Cutting out the section • Fixing the bend • Accuracy of the bend	• In what way is the participant using the bevel • Importance of sticking to the pen marks drawn and associated implications • Look for checking of the angle and reflection NOTE: drawing the cut lines and cutting out may be times when the participant does not need to say anything.
Offset distance • Determine the distance from one bend to the other	• In what way does the participant get the position for the second bend.
Second bend • Mark the centre line • Which direction does the V go • Draw the V • Draw the laps • Cutting out the section • Fixing the bend • Relation to first bend • Accuracy of the bend	• How do the participants find out where the centre line of the second bend goes • How does the second bend differ form the first bend • Look for checking of the correct angle size and reflection • Any thinking linking the two bends and the whole job
(Finished job) • Accuracy of bends • Parallelism of vertical sections	Often for discussion in semi-structured interview • Did they check to see if the finished job satisfied the original requirements • How much can they verbalise about the finished product

Semi-structured interview session

1 Avoid leading questions or questioning techniques.

2 Ask key questions of the participants that needed clarification additional to their responses provided in the SR session (as noted from the table in 5.10). Ask these questions in the order that they relate to the performance of the task.

3 Other possible questions which may provide information on cognitive processing:

> "Let's say that you put the offset downpipe up on a job, and for some reason, you could just tell that it was not right. What about the downpipe would lead you to this conclusion?"
>
> [To use if probing needed from previous question] "What would happen if the bends were different sizes?"
>
> [This is quite a prompt – be careful how you use the responses] "To what degree do you think about, or get a picture in your head, of what the end product looks like in order for you to make it?"
>
> "Would you, or have you ever had to, sacrifice accuracy in order to get the job done quicker?"

Post-interview session

1. Thank the participant for their assistance and that it was valuable. If possible, pick out some aspect of performance that really interested you.
2. Confirm that what now happens to the data and about confidentiality (esp. from their teachers and that real names will not be used).
3. Ask them to remain quiet about what they just did so as not to influence other participants in their cohort.

E: Sample of Information and Consent Forms

COGNITIVE DEVELOPMENT OF SKILL ACQUISITION

Information Sheet for Apprentices enrolled in Trade Certificate Plumbing Courses (and their legal guardians if under 18)

1 August, 2002.

Investigators:

Michaela Inglis, Master of Education (Honours) student, Tel: (02) 6773 5054
Professor John Pegg, Postgraduate supervisor, Director of the Centre for Cognition Research in Learning and Teaching, University of New England, Armidale, Tel: (02) 6773 5070
Dr. David Paterson, Postgraduate supervisor, Lecturer in Education, University of New England, Armidale.

Dear Apprentice,

As part of a research undertaking whilst enrolled as a student at the University of New England, Armidale, in the degree of Bachelor of Education (Hons), I am investigating the learning development of skills that involve some mathematics. More specifically, I would like to observe plumbing apprentices fabricating bends 75mmx100mm Colourbond downpipes.

This study is unique in that it aims to classify the learning development using a model that has proved successful in learning in school-based contexts: the SOLO Model (Biggs & Collis, 1982). No one has yet looked at whether the SOLO Model can also be useful is identifying the development of learning skills in workplace contexts. It is hoped that by being able to show that development of skills can be identified using this model, that eventually similarities between work practices and school-learnt skills can better inform teaching in schools for vocational contexts.

What will be required of you should you consent to allowing the research to take place in your classes.

I am seeking approximately 2 students per year, from first to fourth year.

I am seeking your permission to videotape you individually whilst making these downpipes, in or near the classroom whilst attending TAFE for their regular sessions. Immediately following these videotaping sessions, show you the videotape and ask you to talk me through what you were thinking as you made the downpipe; this information being audio-taped. You would have as much time as you need to make the downpipe up, and the follow-up interview would take no more than 60 minutes.

At no time will anyone other that the three people mentioned on the sheet earlier see the videotapes or hear the audiotapes.

What do you need to do if you would like to participate in this study?

Please sign in the attached Consent Form (with legal guardian's signature if under 18), and hand it to your teacher. Keep a copy of this Information Sheet.

Privacy and confidentiality
At all times the right of privacy, confidentiality and respect for the participants will be observed. Your can withdraw from the project at any time without penalty. Additionally, the researcher (myself) has undergone a Criminal Records Check and completed a Prohibited Employment Declaration form with the NSW Department of School Education. This study has been approved by the Human Ethics Review Committee of the University of New England (Approval No. HE02/155 Valid to 31.12.03). The Human Ethics Officer at the University of New England can be contacted for details on 02 6773 3449 for further details regarding this matter. Data (including videotapes and audiotapes) from this study will be stored in a locked cabinet. Results from this study may be published in a thesis, scientific journals and conference papers, but there will be no information identifying the participants by their name or the name of the campus where the research was carried out.

If you have any further questions or concerns about this study, you can contact me on the phone number on the bottom of this sheet. Should you have any complaints concerning the manner in which this research is conducted, please contact the Research Ethics Officer at the following address:

Research Services
University of New England
Armidale, NSW 2351.
Telephone: (02) 6773 3449 Facsimile (02) 6773 3543
Email: Ethics@metz.une.edu.au

Thank you for taking the time to read this information sheet.

Yours sincerely,

Michaela Inglis

COGNITIVE DEVELOPMENT OF SKILL ACQUISITION

Consent Form for Apprentices enrolled in Trade Certificate Plumbing Courses (and their legal guardians if under 18)

1 August, 2002.

CONSENT

Name of TAFE: ______________________________

Name of student: ______________________________

In signing below, I agree that:

1. I have read the information contained in the *Information Sheet for Apprentices* and any questions I have asked have been answered to my satisfaction. I agree to participate in this activity, realising that I may withdraw at any time. And without penalty. I agree that research data gathered for the study may be published, provided that my name or the name of this TAFE is not used.
2. I also understand that should any information regarding the study change so that it differs from either of the information sheets mentioned above (dated 1st August, 2002), I will be provided with an additional information sheet containing these details and reviewed consent forms for myself.
3. I understand the nature of the research sufficiently well to make a free informed decision to consent to it.
4. I am satisfied that the circumstances in which the research is being conducted will not affect my safety.

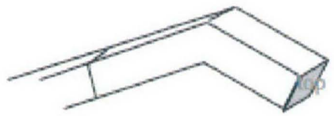
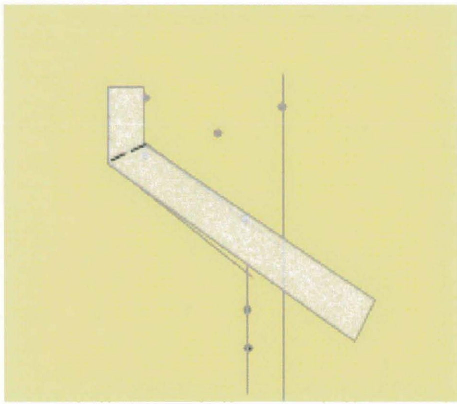
Signature ______________________________:

Signature of Legal Guardian (if applicable): ______________________________

Date:

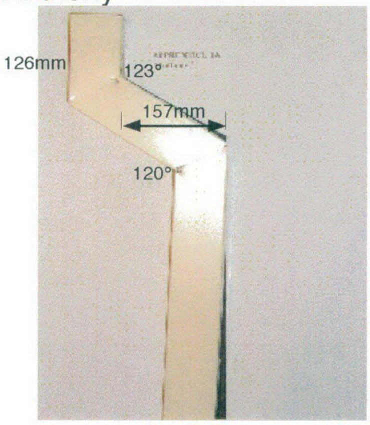
Please forward to your teacher.

F: Excerpt from the Collected, Triangulated and Transcripted Data.

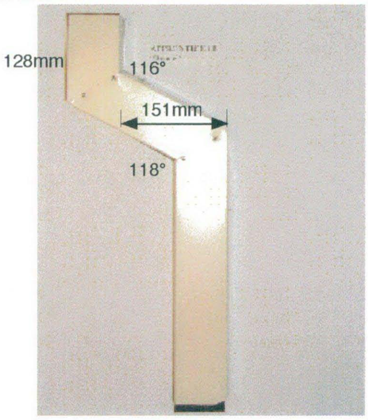
16.53	• From this mark, drew centre line around all sides of downpipe. 	*What's the purpose of using the square?* Just to keep your lines straight with the face of the downpipe there. *I can see you've got the top bit pushed up hard against the pipe…* Yep. You've got to keep that gap even so you use squares.
17.21	• Placed downpipe about 3cm above scale diagram (did not appear to fit scale diagram).  • Hesitated for a long while.	*Some guys just use it as a ruler…* *(laughs)* No. Everything's sort of built for something. *What are you thinking there?* Just visualising if I cut it on that centre line; where it's going to end up when I fold it.

G: Downpipes Fit to Correct Measurements

Anthony

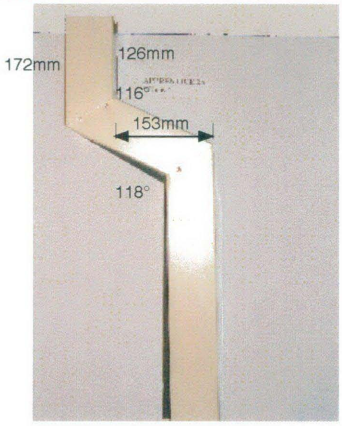


Bruce

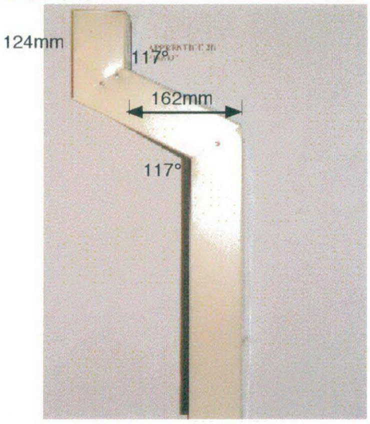


The photographs depict the downpipes superimposed on a black template. This template was an outline of the downpipe made to the specifications outlined in the Job Sheet. Additional measurements relating to the measurements of each product have been annotated on each photograph.

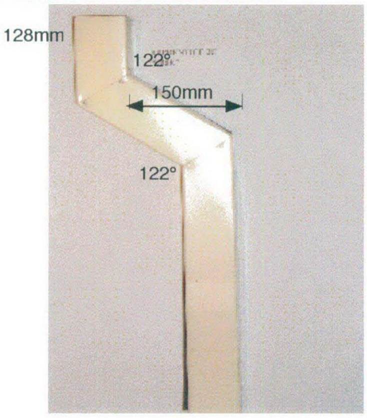
Chris



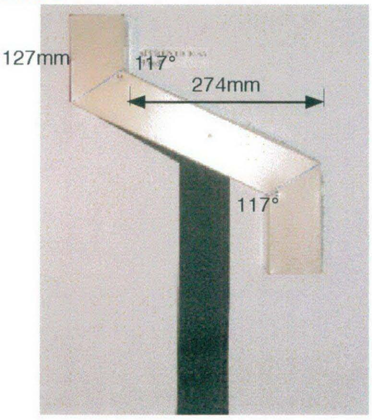
David



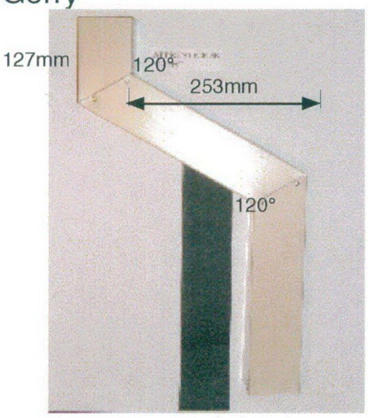
Eddie



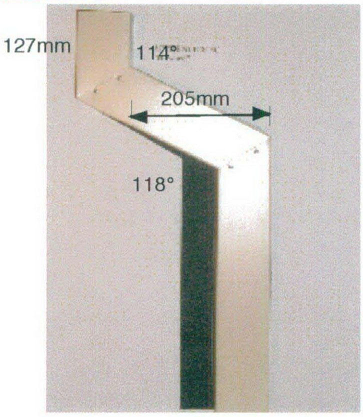
Fred



Gerry



Howard



H: Workplace Appraisal of Downpipes by a Qualified Plumber

Anthony

- Determination: *cannot be used.*
- General appearance okay.
- Proportionately correct.
- Top angle is twisted to the point that you would not be able to use it because it is too noticeable.
- Would work, but appearance (twist) would mean that it would not be acceptable.

Bruce

- Determination: *can be used.*
- General appearance okay.
- Proportionately correct.
- Would be fine to use.

Chris

- Determination: *can be used.*
- Although 125mm is on the wrong side, you could cut it down.
- Angle is out, but it would not really matter on the job site as you would not really notice it.
- Made really well.

David

- Determination: *cannot be used.*
- Although it is parallel, dimensions are out (offset not correct) and therefore it would not fit on the job.
- Joins are a 'bit shabby.'
- Twisted.
- Would get away with the twist, but offset incorrect would mean that you could not use it.

Eddie

- Determination: *can be used.*
- Appearance good.
- Joins are matched up really well.
- No twist.
- Offset 'perfect'.

- Angles are a bit out.

Fred

- Determination: *cannot be used.*
- “6 inches out to start with so there is no way you could use it.”
- Appearance okay
- Slightly twisted, but not much.

Gerry

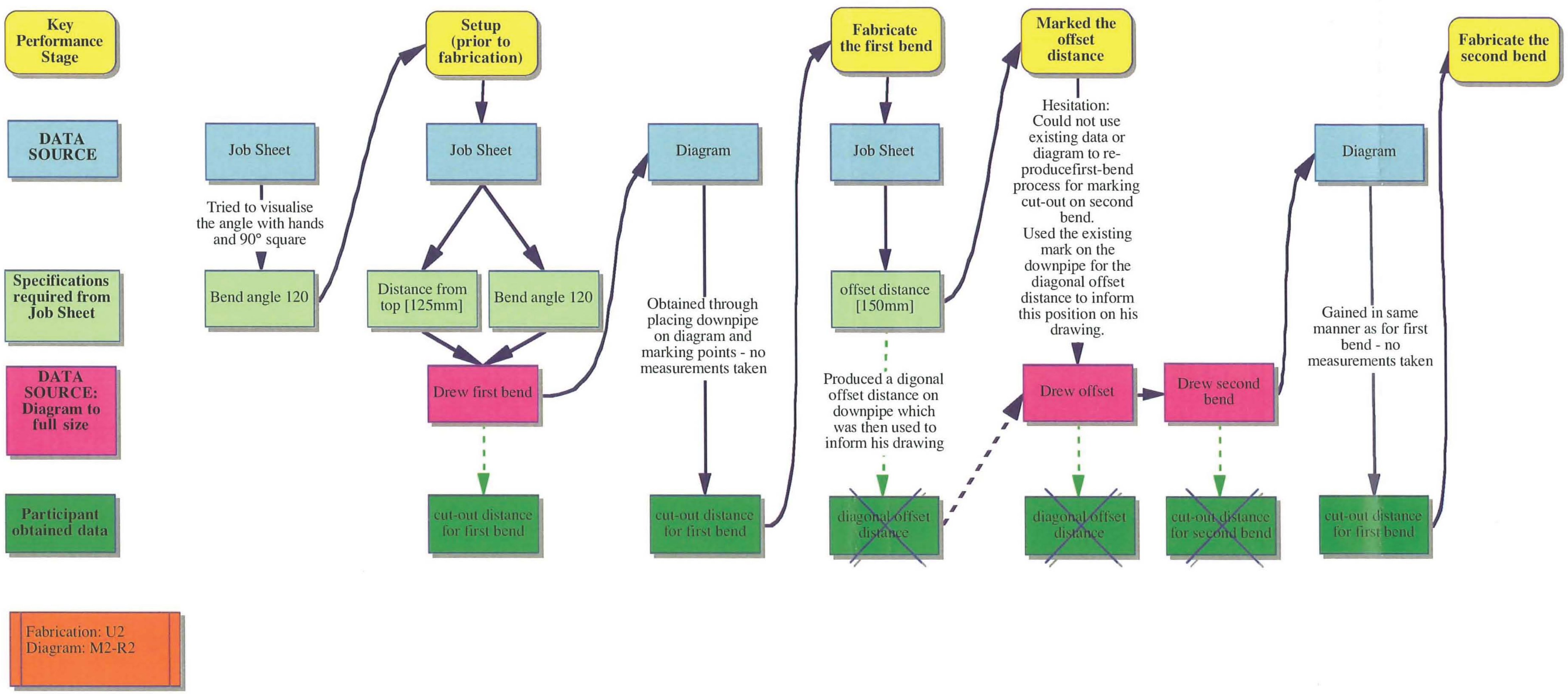
- Determination: *cannot be used.*
- Appearance good.
- Made a slight over-cut with the hacksaw on the second bend, but it would still be okay.
- Construction good.
- If the offset was right, you could certainly use it, it was a good one.

Howard

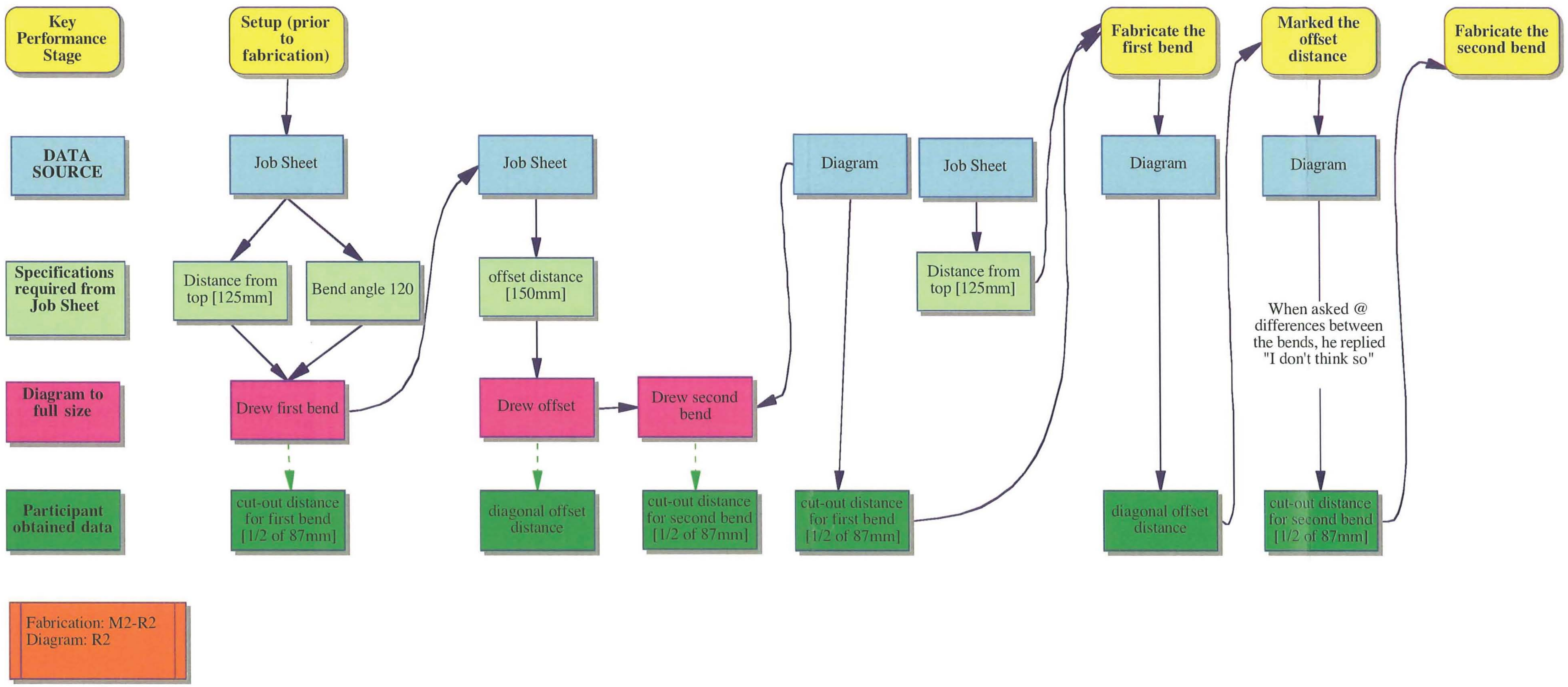
- Determination: *cannot be used.*
- Noticed identical to Gerry, but has not slipped up with the hacksaw.
- Angle is out and offset is out.
- If the offset was okay, you could still use it.
- Good construction, neat. Just proportionally wrong.

I: Flow Charts of Solution Paths

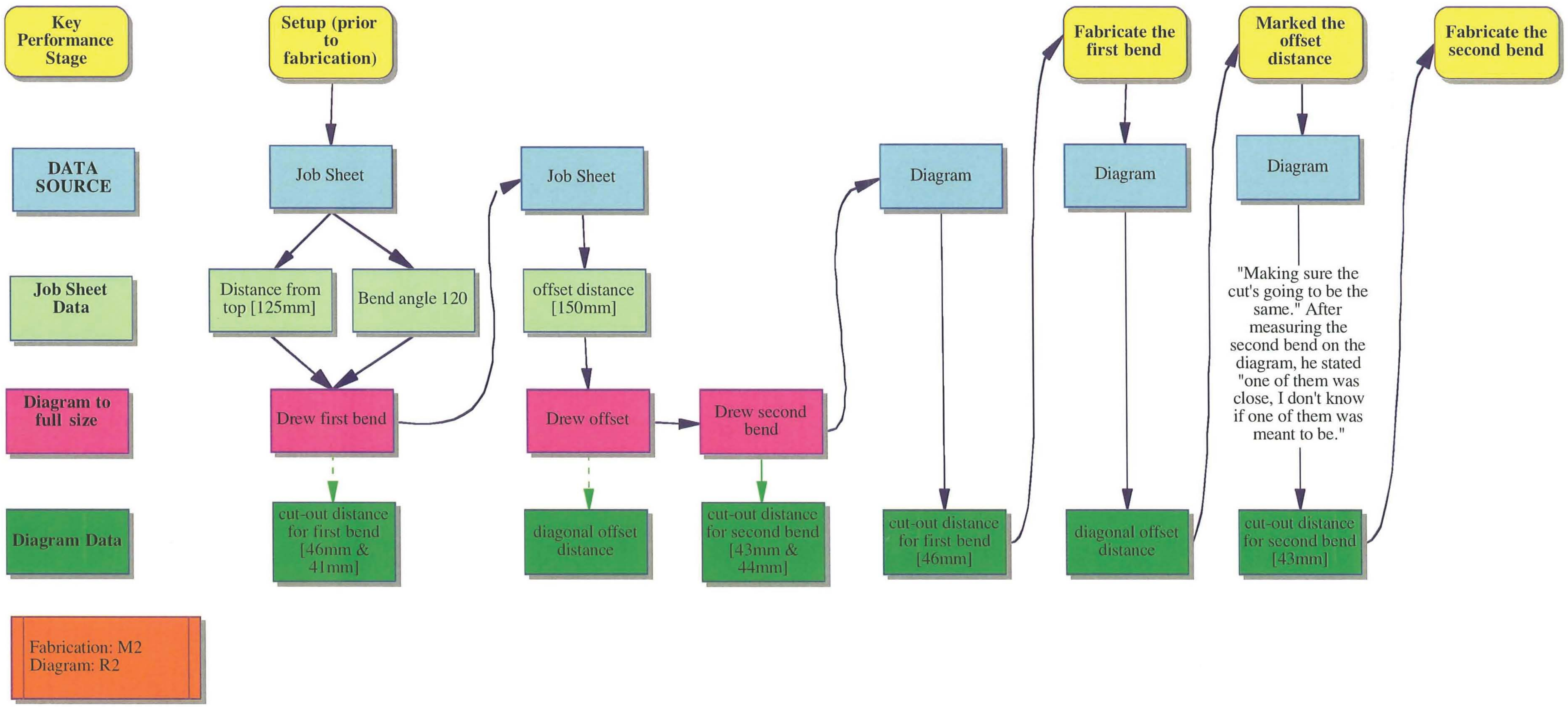
ANTHONY

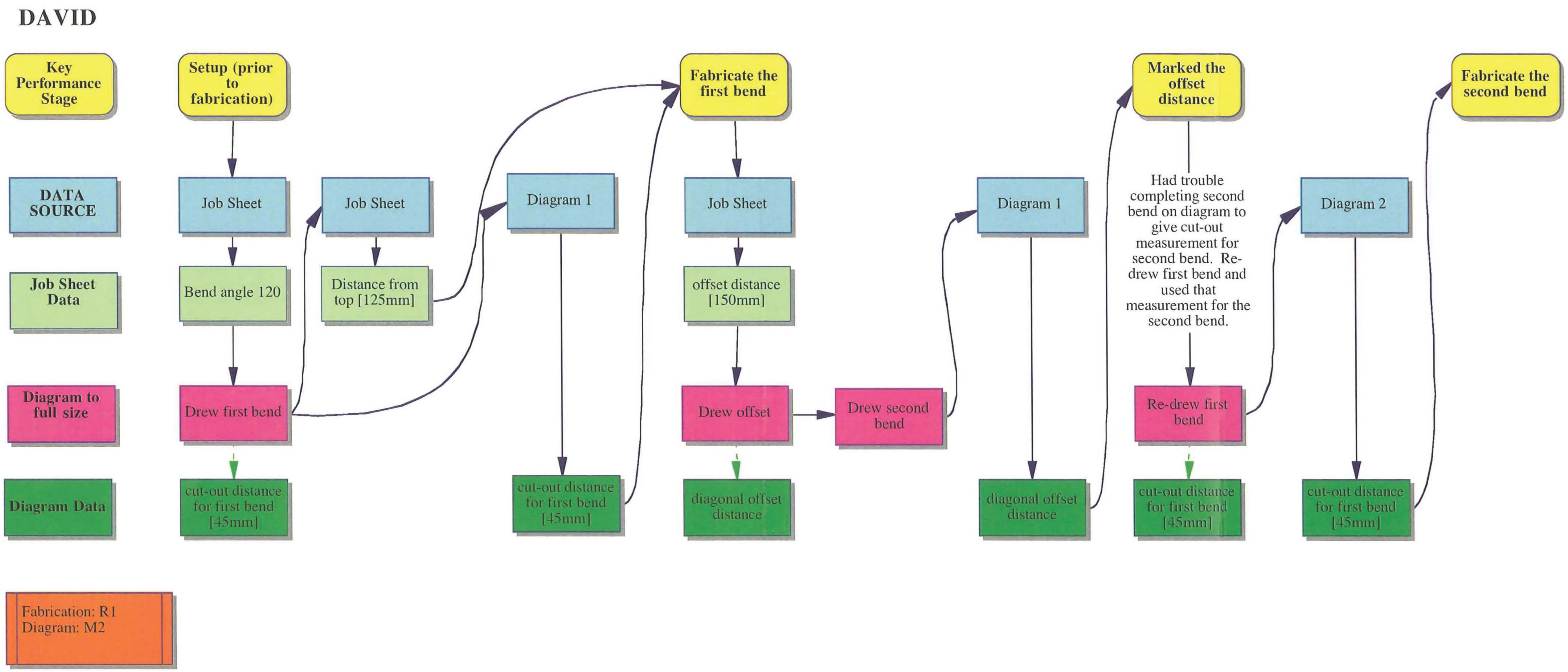

Key Performance Stage
DATA SOURCE
Specifications required from Job Sheet
DATA SOURCE: Diagram to full size
Participant obtained data
Fabrication: U2
Diagram: M2-R2
Job Sheet
Tried to visualise the angle with hands and 90° square
Bend angle 120
Setup (prior to fabrication)
Job Sheet
Distance from top [125mm]
Bend angle 120
Drew first bend
cut-out distance for first bend
Diagram
Obtained through placing downpipe on diagram and marking points - no measurements taken
cut-out distance for first bend
Fabricate the first bend
Job Sheet
offset distance [150mm]
Produced a digonal offset distance on downpipe which was then used to inform his drawing
diagonal offset distance
Marked the offset distance
Hesitation: Could not use existing data or diagram to re-producefirst-bend process for marking cut-out on second bend. Used the existing mark on the downpipe for the diagonal offset distance to inform this position on his drawing.
Drew offset
diagonal offset distance
Drew second bend
cut-out distance for second bend
Diagram
Gained in same manner as for first bend - no measurements taken
cut-out distance for first bend
Fabricate the second bend

BRUCE

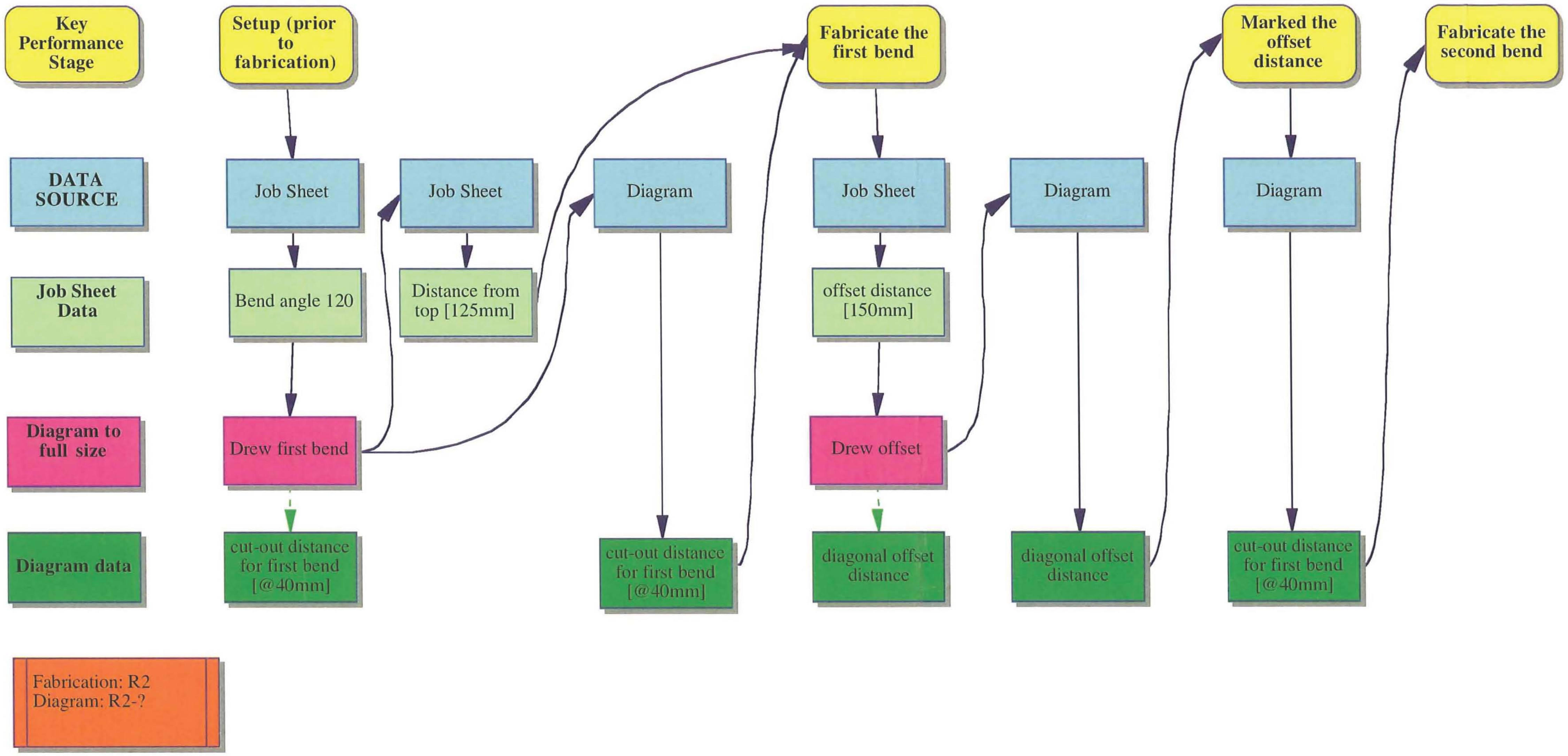

Key Performance Stage
DATA SOURCE
Specifications required from Job Sheet
Diagram to full size
Participant obtained data
Fabrication: M2-R2
Diagram: R2
Setup (prior to fabrication)
Job Sheet
Distance from top [125mm]
Bend angle 120
Drew first bend
cut-out distance for first bend [1/2 of 87mm]
Job Sheet
offset distance [150mm]
Drew offset
diagonal offset distance
Drew second bend
cut-out distance for second bend [1/2 of 87mm]
Diagram
cut-out distance for first bend [1/2 of 87mm]
Job Sheet
Distance from top [125mm]
Fabricate the first bend
Diagram
diagonal offset distance
Marked the offset distance
Diagram
When asked @ differences between the bends, he replied "I don't think so"
cut-out distance for second bend [1/2 of 87mm]
Fabricate the second bend

CHRIS

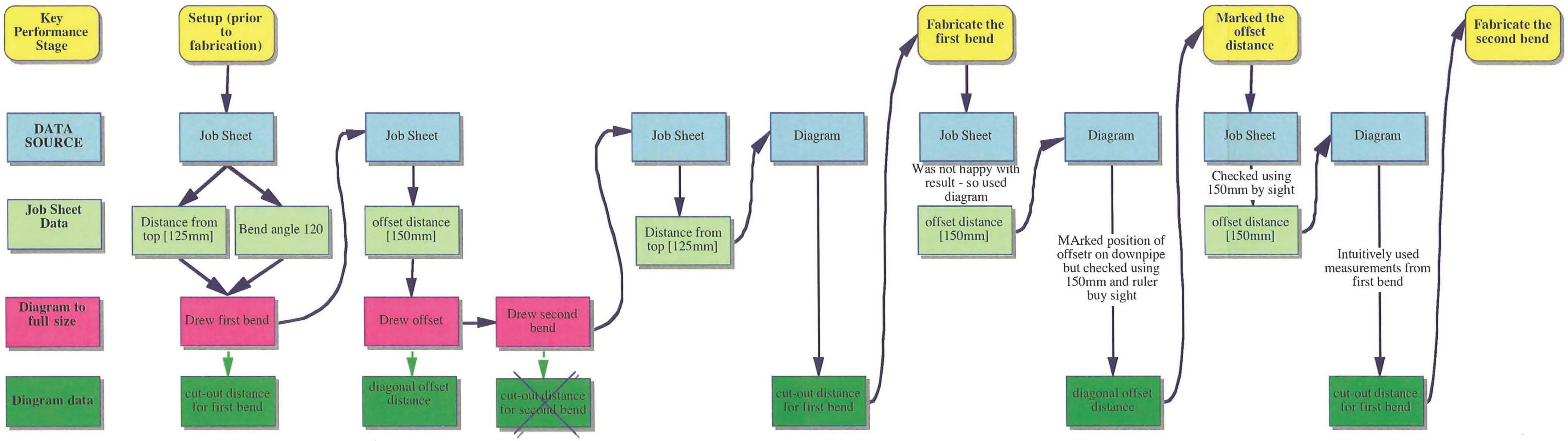

Key Performance Stage
DATA SOURCE
Job Sheet Data
Diagram to full size
Diagram Data
Fabrication: M2
Diagram: R2
Setup (prior to fabrication)
Job Sheet
Distance from top [125mm]
Bend angle 120
Drew first bend
cut-out distance for first bend [46mm & 41mm]
Job Sheet
offset distance [150mm]
Drew offset
diagonal offset distance
Drew second bend
cut-out distance for second bend [43mm & 44mm]
Diagram
cut-out distance for first bend [46mm]
Fabricate the first bend
Diagram
diagonal offset distance
Marked the offset distance
Diagram
"Making sure the cut's going to be the same." After measuring the second bend on the diagram, he stated "one of them was close, I don't know if one of them was meant to be."
cut-out distance for second bend [43mm]
Fabricate the second bend


DAVID
Key Performance Stage
DATA SOURCE
Job Sheet Data
Diagram to full size
Diagram Data
Setup (prior to fabrication)
Job Sheet
Bend angle 120
Drew first bend
cut-out distance for first bend [45mm]
Job Sheet
Distance from top [125mm]
Diagram 1
cut-out distance for first bend [45mm]
Fabricate the first bend
Job Sheet
offset distance [150mm]
Drew offset
diagonal offset distance
Drew second bend
Diagram 1
diagonal offset distance
Marked the offset distance
Had trouble completing second bend on diagram to give cut-out measurement for second bend. Re-drew first bend and used that measurement for the second bend.
Re-drew first bend
cut-out distance for first bend [45mm]
Diagram 2
cut-out distance for first bend [45mm]
Fabricate the second bend
Fabrication: R1
Diagram: M2

EDDIE

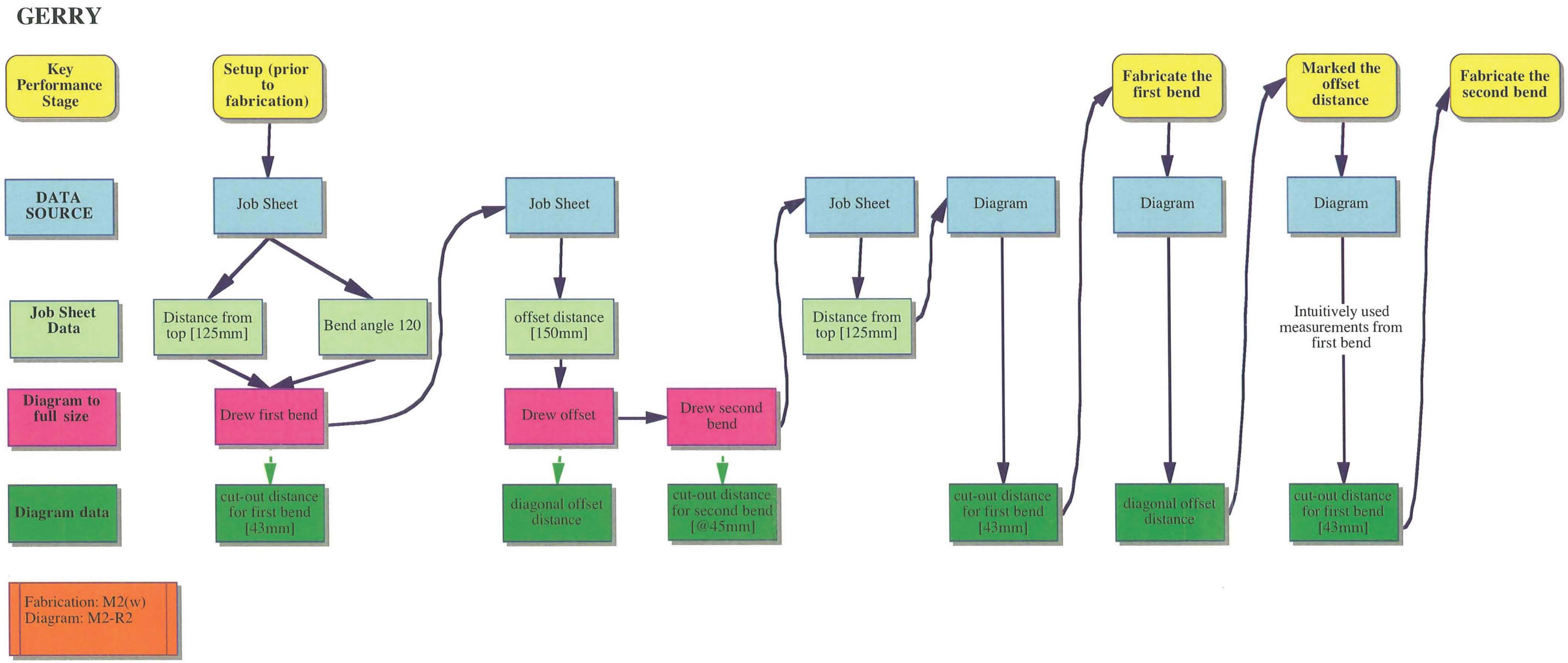

Key Performance Stage
Setup (prior to fabrication)
Fabricate the first bend
Marked the offset distance
Fabricate the second bend
DATA SOURCE
Job Sheet
Job Sheet
Diagram
Job Sheet
Diagram
Diagram
Job Sheet Data
Bend angle 120
Distance from top [125mm]
offset distance [150mm]
Diagram to full size
Drew first bend
Drew offset
Diagram data
cut-out distance for first bend [@40mm]
cut-out distance for first bend [@40mm]
diagonal offset distance
diagonal offset distance
cut-out distance for first bend [@40mm]
Fabrication: R2
Diagram: R2-?

FRED

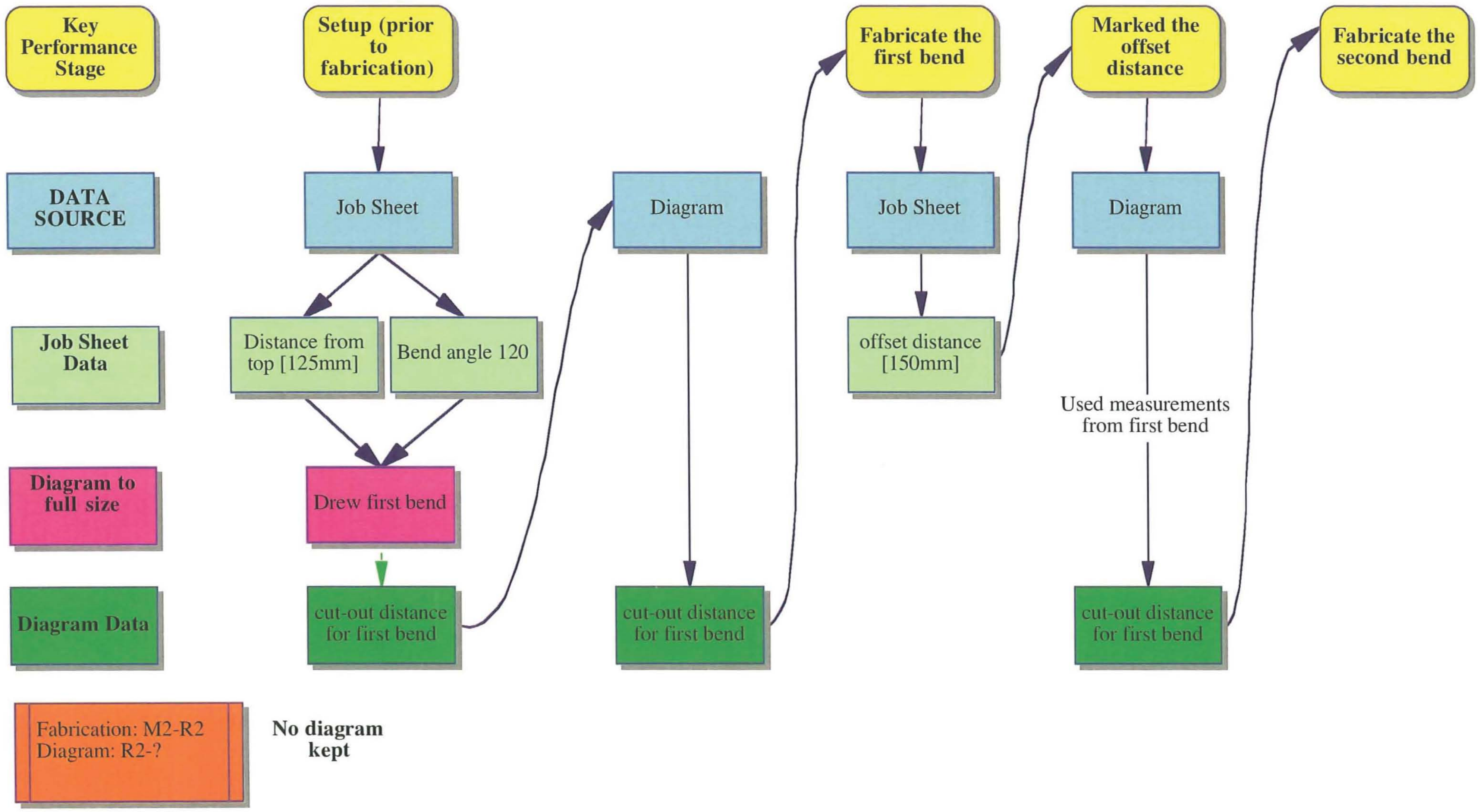


Fabrication: U2-M2
Diagram: M2-R2

Although he drew his diagram, it was not cear what measurements infortmed his fabrication. When he placed the fabrication on the diagram to mark the diagonal offset distance, the fabrication did not match his diagram. It was as if he has a cut-out measurement in his head to use and not to do with his diagram at all.


GERRY
Key Performance Stage
DATA SOURCE
Job Sheet Data
Diagram to full size
Diagram data
Fabrication: M2(w)
Diagram: M2-R2
Setup (prior to fabrication)
Job Sheet
Distance from top [125mm]
Bend angle 120
Drew first bend
cut-out distance for first bend [43mm]
Job Sheet
offset distance [150mm]
Drew offset
diagonal offset distance
Drew second bend
cut-out distance for second bend [@45mm]
Job Sheet
Distance from top [125mm]
Diagram
cut-out distance for first bend [43mm]
Fabricate the first bend
Diagram
diagonal offset distance
Marked the offset distance
Diagram
Intuitively used measurements from first bend
cut-out distance for first bend [43mm]
Fabricate the second bend

HOWARD


Key Performance Stage
DATA SOURCE
Job Sheet Data
Diagram to full size
Diagram Data
Fabrication: M2-R2
Diagram: R2-?
Setup (prior to fabrication)
Job Sheet
Distance from top [125mm]
Bend angle 120
Drew first bend
cut-out distance for first bend
No diagram kept
Diagram
cut-out distance for first bend
Fabricate the first bend
Job Sheet
offset distance [150mm]
Marked the offset distance
Diagram
Used measurements from first bend
cut-out distance for first bend
Fabricate the second bend