Task Context and Applications at the Senior Secondary Level

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A qualitative study was conducted to investigate the impact of prior knowledge of task context on students' approaches to applications tasks and the effect of engagement with context on performance. Prior knowledge mainly enhanced students' understanding of the task having most impact when students constructed a mental picture of the situation. Moderate to high engagement with a task context was not often associated with poor performance. Poor performance was more likely to be associated with no to low engagement. High engagement was not a necessary condition for success as the degree of engagement necessary for success appeared to be task specific.

Introduction

Recent syllabus documents in Queensland (eg, BSSSS, 1992) place an emphasis on applying mathematics to familiar and unfamiliar situations in a variety of contexts. Clarke (1994) warns, however, that instead of the use of contexts providing an emancipatory experience for students in the upper secondary school, for some it may be the source of a further level of difficulty and confusion. Amit (1994) echoes this warning: "as assessments become more complex and more connected to real-world tasks there is a greater [chance] that the underlying assumptions and points of view may not apply equally to all students" (p. 15). Research on the confounding or facilitating effects of context on performance are needed to inform the professional judgement of teachers in framing applications tasks, evaluating student responses, and providing appropriate learning experiences for students.

Selected Literature Review

Not all data in the presentation of an applications problem will have the same strength in cuing information, prior experiences, and processes necessary for its solution. The salience of specific cues for a particular problem solver will contribute to how they perform on a task (Kaplan & Simon, 1990). Cue salience interacts with the problem solver's domain specific prior knowledge and their knowledge of global strategies. Prior knowledge can have a beneficial effect constraining the search space for a problem representation (Helme, 1995) or the reverse effect leading to search in the wrong part of the problem space (Kaplan & Simon, 1990). Aberrant readings of a verbal task resulting from irrelevant prior knowledge interfering with the problem solver's reading of a task can also result in search in the wrong problem space. In applications tasks cue salience and its interaction with prior knowledge are of particular importance. Furthermore, problem solvers are unlikely to engage with the context of a task with which they are unfamiliar to the same degree as, or in a similar manner to, a person who has prior experience of the situation (Masingila, Davidenko & Prus-Wisniowska, 1996).

This paper reports part of a much broader study which investigates the effects of context on students' approaches to, and performance on, applications tasks in Mathematics B, the main pre-tertiary mathematics subject in Queensland. Specifically, the following questions are addressed here:

1. What effect does prior knowledge of the task context have on students' approaches to applications tasks?
2. What effect does engagement with context have on performance on applications tasks?

The effects of prior knowledge of the task context will be examined through an investigation of how students "exploit the texture of their experience as a resource in their mathematical activity" (Noss & Hoyles, 1996, p. 44). For adolescents in high school, this experience may be vicarious through knowledge developed in other academic subject areas or their general encyclopaedic knowledge of the world, or, truly experiential developing from their personal experiences outside school or in more practical school subjects. The terms *academic knowledge*, *encyclopaedic knowledge* and *episodic knowledge*, respectively, will be used in the following to distinguish between these sources of prior knowledge. An insight is sought into the interplay between the lived-in experience of students and their mathematical activity in attempting to solve these tasks.

The Study

The Participants

The study was conducted in two public high schools in a large provincial city. Data collection occurred over a six month period during which contact with both schools was continuous. Forty-three Year 11 and Year 12 students participated in the study.

Multi-Site, Multi-Case Design

The use of one site for a study such as this would allow the researcher "to describe, understand and explain what [had] happened in a single, bounded context" (Miles & Huberman, 1994, p.172). The purpose was to glean "a well-grounded sense of the local reality". Within that one site multiple individual case histories (eg, of students and teachers) could be studied and integrated to form a picture of that local reality. However, a multi-site design increases the applicability of the study's findings to other similar settings allowing idiosyncratic nuances of a particular site to be identified as well as determining what is of a more general nature. A more pressing reason for choosing a multi-site, multi-case design was to deepen understanding and explanation of a very complex setting (Miles & Huberman, 1994).

Development of Applications Tasks

In all, 18 applications tasks were developed. Illustrative examples are included in an appendix. These tasks differed in terms of familiarity, complexity and degree of contextualisation. An *unfamiliar application* was taken to mean an unrehearsed mathematical application to a life-related situation where the context (the situation) was unfamiliar to the students in the sense that they had not mathematized a similar situation previously but the mathematical techniques needed to solve the problem were not unfamiliar (BSSSS, 1994). The *complexity* of the task "depends on how obvious the choice of techniques is, the number of techniques required, and the amount of guidance given to students" (p. 1). The term *degree of contextualisation* is meant to convey the range of embeddedness that exists between the mathematics that can be used to model a situation and the description of the situation.

Administration of the Tasks

Students were videotaped as they attempted to solve a task individually. The role of the researcher during the task solving session was to be as unobtrusive as possible unless the student was experiencing grave difficulties accessing the problem when students were invited to ask clarifying questions and offered prompts to enable them to start in order to attempt to determine which aspects of the task were preventing them from accessing it. All interactions were recorded.

For all phases of the data collection except the second, students were given at least one task to complete and if time permitted, a second task was completed. During the second phase of data collection six students were chosen by the researcher, in consultation with the Head of Department, to attempt a series of four unfamiliar applications tasks that were of differing complexity and degree of contextualisation (namely, the Ecosystem Problem, Road Construction Problem, Road Accident Problem and Painting Problem). It turned out that one of the tasks (the Painting Problem) was similar to a task students had seen previously (the Picture Theatre Problem, Brodie & Swift, 1993, p. 252). It was decided not to discard the task but to use it to develop tasks that were parallel in mathematical content but embedded in different contexts to investigate the effect of context in these circumstances. To avoid presentation bias students attempted these tasks in different order. The basis for selecting particular students was their facility with mathematical techniques on school assessment, their success with applications tasks in the school assessment programme, and their degree of ease with the situational context in which the tasks were attempted as demonstrated in their first task solving session.

The Student Interview

Semi-structured stimulated recall interviews were conducted by the researcher immediately following the completion of the tasks. The interviews were recorded using videotape with audio-cassette tape as a backup. The students reviewed the videotape of their task solving session in conjunction with the script of the task during the interview except for 3 instances where technical difficulties prevented this when the script alone was used as a stimulus. Students were asked to draw diagrams where appropriate during the interview to illustrate their understanding of the context and problem goal as diagrams provide insight into students' understanding of the structure of a problem by revealing their understanding of the relationships between the various components of the problem (Shigematsu & Sowder, 1994). Nunekawa (1994) and Diezmann (1995) recommend monitoring the dynamic use of diagrams throughout the solution process to see the changes in relationship between students' perceived structure of the problem and the actual structure. The use of the video-taped task solving sessions as a visual stimulus throughout the interview allowed both the interviewer and the interviewee to track the student's developing understanding of the task structure by discussing their changing perception of the task as observed in their changing use of diagrams throughout the review of the task solving session.

Analysis

All interviews and task solving sessions where there were interactions between the student and the researcher were transcribed. The interviews were analysed using the qualitative data analysis software QSR NUD.IST (QSR, 1997). NUD.IST facilitates "grounded theory" construction (Strauss, 1987) which attempts to capture and interrogate the meanings emerging from data. This is achieved by constructing and exploring new categories and themes as they arise from the data then refining these through a "process of progressive category clarification and definition" (Tesch, 1990, p. 86). According to Tesch, the main theory building functions of NUD.IST are the location of places where categories intersect and "the corresponding search for counter-evidence" (p.165).

Results

Prior Knowledge of Task Context

Disconnections Between Students' Experience and Task Context: Unfortunately for students, there are often many disconnections between their lived-in world and the contextual situations described in classroom tasks. This is illustrated by the case of A56 whose claim that he knew "a fair bit" about mechanical things was substantiated by his description of what was happening in the Shaft Problem.

> A56(Task7): You have just got a shaft that has been worn down.
> I: Uhmm.
> A56(Task7): *...through spinning.*
> I: So you assume it was spinning to wear down?
> A56(Task7): Oh, yes.
> I: That would be more than likely?
> A56(Task7): *A cylinder, yes.* So it's changing the diameter of the shaft.

He was in the realms of his lived-in experience, his episodic knowledge, so he was quite willing to garnish his description with elaborations from his personal experience. He was much less confident in his description of the mathematics of the situation.

> I: In terms of maths, what sort of equation is it?
> A56(Task7): The derivative.
> A56(Task7): *Of something, yeah.*
> A56(Task7): And so I'd have to take the integral of it.
> I: All right. There you are. Get going.
> A56(Task7): *Awh, god. That's not one of the rules is it? Because if it is I wouldn't have a clue.*

His mathematical knowledge was something he had acquired at school. It was disconnected from his experience out of school even when the context of a task was something so familiar to him. This may be explained, however, by the fact that in a written representation many of the situational aspects of a problem are lost unless they can be structured in a way to arouse sense-making connotations, which means, according to Nunes, Schliemann, and Carraher (1993), not losing the referents in a situation that make it meaningful in the everyday world.

Sense-making Through Making Connections: During discussions with the interviewer the student was able to make connections between the mathematical meanings of the written task and the everyday meanings of the familiar situation as shown in the next exchange when he encountered the cube root of a negative number. When pressed for possible reasons for this number being negative his episodic knowledge of the context came to the fore.

> I: But the negative couldn't have been something like the amount of wear? It couldn't have been some indication of that?
> I: Now if it's negative, it's just showing you that the wear is decreasing, the rate [of wear] is decreasing. You don't think it was that situation?
> A56(Task 7): *Oh, yeah, because it is, although the wear would increase as time went by.*
> I: The actual amount of wear would increase as time went by?
> A56(Task7): Well, using a cylinder, a shaft, using the words instead of the numbers, because *once you get a little bit of gap it starts flogging in.*
> I: Yes, you get a lot more tool vibration.
> A56(Task7): *The tool vibrates more so you are going to get more wear.*
> I: Yes, so you would expect the wear to be increasing?
> A56(Task7): *Yeah.*

I: The actual rate at which it is happening is increasing so another thing to explain the negative would be the diameter itself saying you are taking away from the diameter and the diameter is decreasing. That's the only other thing.

Looking at his mathematical activities through the meanings of his experiential knowledge is not something he usually tried to do. He had a tendency to work on the two separately and did not appear to realise that if he could integrate the contextual and mathematical meanings, the situational context could guide his solution throughout by helping him to make sense of what he was doing mathematically.

A56(Task 7): Well, I go through the numbers and work out...get an answer first off, then look at the actual situation and if it won't suit the situation then, then I'm totally wrong.

In the remainder of this section, students' ability to establish some connection between the meanings implicit in the mathematics of the written tasks in the study and the meanings derived from their prior knowledge of the situational context, as just illustrated, will be investigated.

Types of Prior Knowledge Displayed: A case-level meta-matrix (Miles & Huberman, p. 178) of the data from the first round of collection (Year 12 data from School A) was used to categorise student responses to questions regarding what prior knowledge, if any, they had of the task context. The affirmative responses were categorised as academic knowledge, encyclopaedic knowledge and episodic knowledge by the researcher. The type of prior knowledge that students mentioned that they could have drawn on was mainly academic from subjects such as Biology and Multi-Strand Science or general encyclopaedic knowledge. There was only the one example (just described) where the student's knowledge was categorised as episodic. Of the ten instances of prior knowledge displayed, there were only three cases where it had an impact on the student's solution. These all involved an enhancement of the student's understanding of the task.

In the second round of data collection it was decided to vary the task format and tailor tasks more towards personal background experiences of students. Three of the tasks (Ecosystem Problem, Painting Problem and Road Accident Problem) drew on more general contexts with the potential to involve academic and encyclopaedic knowledge whereas the remaining tasks were expected to activate the episodic knowledge of students. The Road Construction Problem was chosen on the basis that it was believed to have potential to engage students' interest because road construction was something they would see on a daily basis as, at the time of the study, major road works were underway near the school. The remaining tasks had a sports context (rugby league football and ice hockey) as the researcher knew that several of the students involved in the study played or followed rugby league football or hockey and these sports were prominent in the school community. As the researcher was not as familiar with the backgrounds of the students at School B, she did not set tasks that she expected would necessarily tap into students' episodic knowledge at that site.

A case-ordered meta-matrix was used to analyse the student responses for the remaining rounds of data collection. These were then categorised as above. The type of prior knowledge of the context reported for the Year 11 sample from School A was as anticipated. The results from students who attempted multiple tasks confirmed that this was a task specific rather than student specific effect. Just what effect, if any, these different sorts of prior knowledge had on student solutions or student interest needs a closer examination, however.

There were three cases where student's prior knowledge interfered with their development of a solution, however, in two of these cases the students involved were able to overcome this. In the other case the student's academic and encyclopaedic prior knowledge interfered producing an aberrant reading of the task. There were a further 14 cases where the prior knowledge reported or displayed appeared to be redundant as it was not used at all. Only two of these were classified as episodic with the remainder evenly divided between academic and encyclopaedic. The remaining cases where student's prior knowledge had a positive impact on their solution attempt will be examined further.

Use of episodic knowledge: Only seven of the thirteen students who attempted the Road Construction Problem reported using their episodic knowledge in any way. Three students even denied that the situation of a road being built was something they knew about. When used, episodic prior knowledge had the effect of enhancing a student's understanding of the problem situation having the most impact when students used it to develop a mental picture of the situation.

With the parallel tasks to the Picture Theatre Problem, four students dismissed the context once they realised it was a parallel problem. Three other students who attempted the Ice Hockey Problem all played field hockey and reported using their prior knowledge to understand the problem situation and construct their representation of it as they had visualised a field and an ice hockey player skating towards a goal. A72 also reported being able to use her visualising skills throughout the problem to check that she was on track. The remaining student attempted the Rugby Goal Problem which he tried to solve using his tacit knowledge of the game.

> A66(TASK13): ...See, you want a plain angle of 45 degrees. You come back - sort of margin of error, sort of margin for error like. If you want to, if you want to go to the centre of that...[meaning the crossbar].
>
> A66(TASK13): You want to go for the centre out...and if you want that to be 45 degrees and that is 13 that will have to be 13 as well.

Only two students from School B reported any prior episodic knowledge of task context. B4's father was in property and she had seen preventative measures such as fences to stop the erosion of banks at the side of roadways. This only helped to make her more comfortable with her understanding of the context in the Road Construction Problem. B7, however, chose a periodic function as her model in the Tide Problem and used her episodic knowledge of tides to reassure herself that this was a sensible model.

Use of academic knowledge: Although five of the nine students who attempted the Ecosystem Problem and three of the seven students who attempted the Road Accident Problem reported having prior knowledge from academic subjects that would have assisted them in understanding the context of these problems, no student felt this assisted them with their solution processes greatly beyond this except A85.

> A67(TASK12): I understood what it was about - not how to do it.

A85 considered the Ecosystem Problem to be much more practical than the Road Construction Problem. This was in direct contrast to most other students who viewed the Ecosystem Problem as little more than an academic exercise.

> A85(TASK9): I liked this one actually because it was, umm, more practical to...I could understand it [more easily] than the other one - you know, the lane, the one with the lane. I couldn't visualise that one but I could [this one].
>
> A85(TASK9): Awh...ummm...I found it [the context] very [useful]. I liked it. Yeah, that was very easy for me to understand and it was a...umm...like a realistic problem for me.

The possible reason for this was her affinity with the context.

> A85(TASK9): I think I know in my mind I kept visualising fields of grassland and bushland and woodland.
>
> A85(TASK9): Yeah, I can relate to it. That's what I am trying to say.

When asked if it would have made a difference to her if the context had been jelly beans rather than ecotypes she replied:

> A85(TASK9): Umm, probably, because...umm...I wouldn't have been able to understand it with jelly beans because this I can sort of grasp the realness of it.

Her affinity with the context of this problem appears to come from her prior academic knowledge of the situation developed through her study of Geography together with her ability to transform the change diagram into something so concretely visual in her mind. With the Road Construction Problem she could not visualise the situation at all but this was influenced by an aberrant reading of the context initially. The students who said they did not have an academic knowledge of the context of these tasks did not feel disadvantaged, however. This was because they felt the context was easily understandable anyway, or they were dismissive of the context.

Use of encyclopaedic knowledge: Encyclopaedic knowledge of the task context mainly reassured students about their understanding of the problem. It allowed them to speculate on possible reasons for the events described in the tasks happening and whether or not they thought the scenarios were feasible. There were, however, three cases where encyclopaedic knowledge was used to choose between two mathematical options, eg, B1 used her encyclopaedic knowledge to choose between two possibilities in the Rain Problem.

> B1(TASK16): Well, you are going to...actually there is going to be two possibilities and *it is going to have to be negative because of the drought.*

In another two cases, encyclopaedic prior knowledge was used to check interim or final results. A85, for example, was able to judge that her final speed for the car which ran off the road in the Road Accident Problem was unreasonable.

> I: So, now you gave a little giggle at this stage? Why was that?
> A85(TASK12): The answer was ridiculous.
> A85(TASK12): Yes, very unrealistic unless you had a rocket.

Summary: Students in the study displayed prior knowledge of the task context which was of an academic, encyclopaedic or episodic nature. The types of prior knowledge reported appear to be related to the nature of the task and were not student specific. The effects of this prior knowledge on the development of a task solution varied. In a few cases it interfered with the student's development of a solution, in some cases it appeared redundant, not being used at all, but in the majority of cases it had a positive impact. In most cases prior knowledge enhanced students' understanding of the task having the most impact when it enabled students to construct a mental picture of the situation. There were a few cases where prior knowledge was used to enhance decision making enabling students to select an appropriate mathematical model or choose between two mathematical options. In other cases, prior knowledge was used to check progress or interim or final results.

Engagement with Context

Qualitative data from all cases were scaled by the researcher using the two dimensions degree of engagement in task context and quality of performance. The task videotapes and student reviews of these during the post-task interviews were examined to scale the cases along a continuum from no to high engagement. The task scripts were then used to scale the task solutions along a continuum from being unable to make a start or totally misinterpreting the problem to a totally correct solution with no conceptual or mechanistic errors. These two dimensions were then used as axes for scatterplots (Miles & Huberman, 1994, p. 197) where cases were positioned in the space formed by the respective axes so that similarities and contrasts among cases could be seen. In those cases where the researcher assisted the student two values have been shown with an arrow indicating the direction of the change from the point in the solution when the researcher intervened.

Figure 1 shows the scatterplots for the Year 12 and Year 11 samples, respectively, at School A. Few students were successful in the Year 12 sample and there was little to no engagement with the task context. This is in stark contrast to the Year 11 pattern with approximately half the cases showing at least partial success and some to high engagement with the task context. The clustering of cases by task foreshadowed the possibility that there could be task specific effects so the cases for particular tasks were plotted on separate scatterplots (Figure 2).

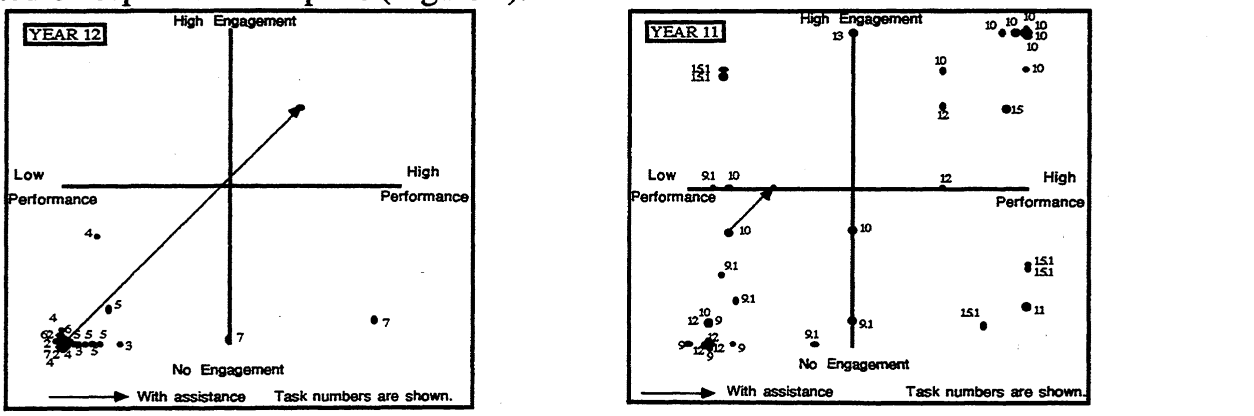

Figure 1. Scatterplots of Relationship of Degree of Engagement with Context and Performance on All Tasks at School A by Year Level

From Figure 2 it would appear that to be successful on the Road Construction Problem a high degree of engagement with task context is necessary. In contrast, the Ecosystem Problem does not appear to require a high degree of engagement with the context to be successful although the students in the study had only limited success with this problem. The results for the parallels with the Picture Theatre Problem appear to be contradictory. A confounding factor with this problem was the fact that some of the students used their knowledge of the solution to the parallel problem rather than developing their solution from the context. These students were quite successful but only one of them reported relying significantly on the context. If these students had not seen the parallel problem they would have had to engage with the context a lot more to construct a suitable representation for the problem. The other two students made little progress as they both made a similar misinterpretation of the Ice Hockey Problem believing that the skater was restricted to skating towards the goal only in the two metre width of the goal mouth. Success with the Road Accident Problem appears to be related to the level of engagement with task context but the sample of cases is small so this would need further confirmation. The more successful students on this task, B5 and A72, displayed a much higher level of engagement with the task context than the other students.

Figure 3 shows a scatterplot of the data from School B. The level of engagement with task context varies for the successful students with the particular task ranging from none to high. The unsuccessful students, however, were all unable to engage, without assistance, to a significant extent with the context of tasks which other students had found it necessary to do so to be successful.

A cross-site scatterplot is shown in Figure 4 for all the tasks. It would appear that moderate to high engagement with task context is not often associated with poor performance. Poor performance on tasks is more likely to be associated with no to low engagement with the task context. High engagement with the task context is not a necessary condition for success as it appears to be dependent on the nature of the task as shown in Figure 2.

Discussion of Results and Implications

The results from this study indicate that prior knowledge of the situational context of an applications task can have a positive effect on a student's understanding of a task especially for those students who have well developed visualisation skills. However, the effects of prior knowledge are not always positive with it sometimes producing no effect or actually interfering with a student's understanding of a task. The findings of this study are therefore in agreement with Clarke (1994) and Amit (1994). Episodic prior knowledge is more likely to have a positive effect than academic or encyclopaedic knowledge. Teachers also need to realise that not only will the effects of prior knowledge differ from student to student because of differing backgrounds but also the fact that particular students have had the same background experiences does not mean that memories of those experiences will be activated for all students when relevant or have similar impact on the task solution when they are activated.

Many students in the study were unable to engage with the context of an

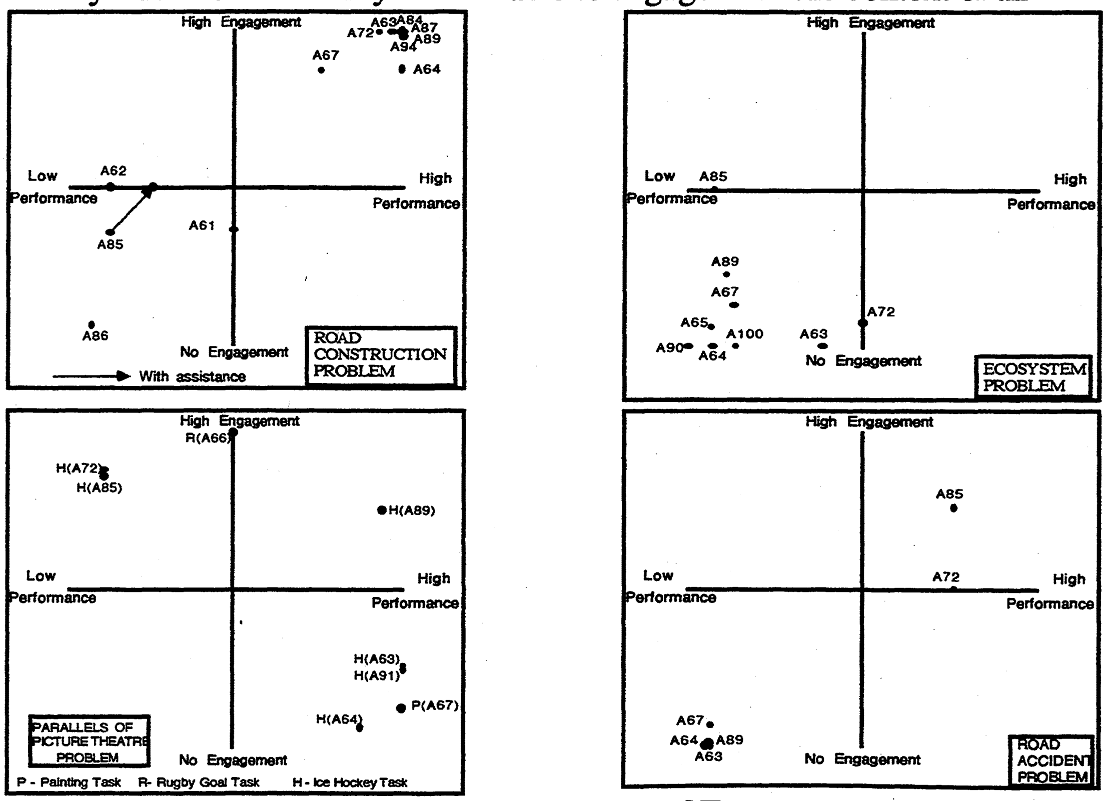

Figure 2 Scatterplot of Relationship of Degree of Engagement with Context and Performance on Specific Tasks at School A(Year 11)

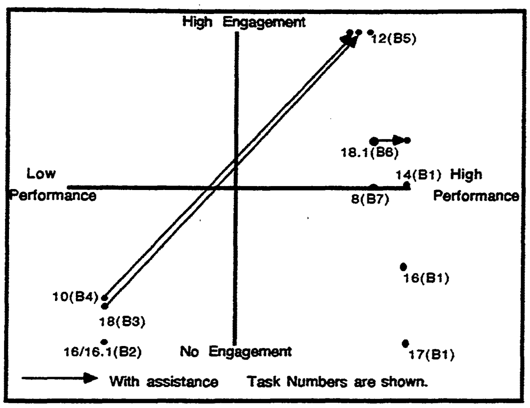

Figure 3. *Scatterplot of Relationship of Degree of Engagement with Context and Performance on Specific Tasks at School B*

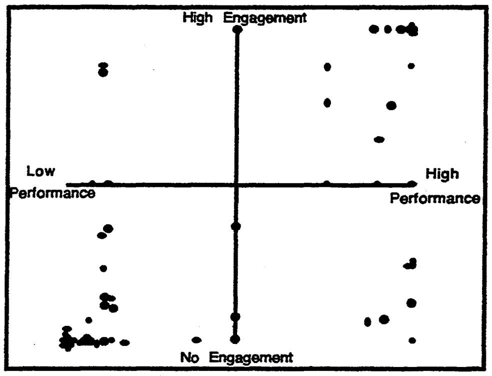

Figure 4. *Scatterplot of Relationship of Degree of Engagement with Context and Performance on All Tasks Across Sites*

applications task to any significant degree particularly when tasks were used that were similar to those used in the classroom and school assessment program (eg, School A Year 12). This would not be problematic if tasks are set which avoid the necessity for such engagement for success, however, if the rationale of syllabus documents is to be taken seriously tasks need to be set which require engagement with context. It is impossible to develop "the modes of thinking which provide ways of modelling situations" (BSSSS, 1992, p. 1) in our environment by continually attempting tasks that avoid any significant engagement with the task context on the part of the problem solver.

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Appendix

Example Tasks

The Shaft Problem (TASK 7): The diameter of a cylindrical shaft is gradually reducing through wear. The rate at which the diameter is changing is given by

$D'(t) = -0.144t^2$ *mm per month for* $t > 0$.

After 1 month of continuous use the diameter is 500.12 mm. How many months will the shaft have been in use before the wear is 1 mm?

Road Construction Problem (TASK 10): A new traffic lane (of minimum width 6 metres) is to be added to a section of highway which passes through a cutting. To construct the new lane, engineers need to excavate an existing earth-bank at the side of the roadway which is inclined at 25° to the horizontal. This will make the inclination steeper. Local council regulations will not allow slopes greater than 40° due to the potential for erosion. Determine if the new traffic lane can be excavated without expensive resumption of the properties at the top of the bank which is 7 metres above the road surface. [List any simplifying assumptions you have had to make.]