From Description to Analysis in Technology Aided Teaching and Learning: A Contribution From Zone Theory

Peter Galbraith
University of Queensland
<p.galbraith@mailbox.uq.edu.au>

Merrilyn Goos
University of Queensland
<m.goos@mailbox.uq.edu.au>

We apply an adaptation of Valsiner's Zone Theory to the structuring of activities as they occur within teaching-learning contexts. A challenge exists to develop frameworks within which to describe, theorise, and interpret the range of learning activities engaged by teachers and students in technology enriched settings. We illustrate the approach through applications to the analysis of literature comment, to classroom episodes, and to professional development experiences.

A continuing challenge exists to develop frameworks within which to describe, theorise, and interpret the range of learning activities engaged by teachers and students in technology enriched settings. Such frameworks serve at least two purposes: first, to capture and interpret characteristic forms of technology use exhibited by students and teachers in classroom learning episodes; and second, to theorise teaching actions as they are used to orchestrate the learning of students. This is important also for teacher education in providing concepts and metaphors for analysing pedagogical actions as implied by classroom events and teaching moves, that may otherwise be seen merely as separate incidents or individual preferences.

While various approaches have included, for example, the analysis of technology use from a *mathematical standpoint* (Doerr & Zangor, 2000) and in terms of *profiles of behaviour* (Guin & Trouche, 1999), our own conceptualisation of technology use in mathematics classrooms represents a *sociocultural orientation*, in that it encompasses interactions between teachers and students, amongst students themselves, and between people and technology, in order to investigate how different participation patterns offer opportunities for students to engage constructively and critically with mathematical ideas (Goos, Galbraith, Renshaw, & Geiger, 2000). That is, while technology may be regarded as a mathematical tool (*amplifies capacity*), or as a transforming tool (*reorganises thinking*), it may also be regarded as a cultural tool (*changes relationships between people, and between people and tasks*). A central tenet of sociocultural theory is that human action is mediated by cultural tools, and is fundamentally transformed in the process (Wertsch, 1985). Within particular knowledge communities, then, tools are cultural resources that re-organise, rather than merely amplify, cognitive processes through their integration into human practices.

To understand and explore this appropriation we have considered and utilised alternative but related formulations of a central concept of sociocultural theory—Vygotsky's notion of the zone of proximal development (ZPD). First, the most widely known definition of the ZPD is as the distance between what a learner can achieve alone and what can be achieved with the assistance of a more advanced partner or mentor. Second, the conceptualisation of the *ZPD in egalitarian partnerships* which suggests that there is learning potential in peer groups in which each partner possesses some knowledge and skill but requires the others' contribution in order to make progress. Third, the operation of the ZPD concept as stimulated by the *challenge of participating in a* *classroom* constituted as a community of practice. We have previously reported how, in community of practice classrooms, students are challenged to move beyond their established competencies and adopt the language patterns, modes of inquiry, and values of the discipline. Such a classroom environment, representative of an active community of learners, is then augmented by the availability of technology as another agent in the search for powerful and meaningful mathematical learning and application. In this paper we extend our sociocultural orientation to encompass and integrate additional components of *zone theory* as described in the following sections. Our aims are:

(a) to adapt elements of zone theory to structure and analyse the actions of teachers and students in learning settings; and

(b) to develop implications of zone theory for application within classrooms, teacher education and professional development.

Valsiner's Zone Theory

While the ZPD directs attention to what can potentially be learned, its usefulness is dependent on other enabling conditions. Firstly teaching activity must be appropriately directed, and secondly the environment must be supportive of the intended learning. These conditions involve person-environment relationships and we have begun to explore a theoretical system to conceptualise the structure and impact of these relationships. To this end we have adapted the theory, designed primarily as an explanatory structure within the field of human development (Valsiner, 1997) to apply to teacher-student relationships—where "teacher" can be taken to include peers under relevant circumstances. We are interested particularly in classroom based teacher-student-technology interactions. The Valsiner theory adds the Zone of Free Movement (ZFM) and the Zone of Promoted Action (ZPA) to the Vygotskian Zone of Proximal Development (ZPD) as frameworks for theorising teaching and learning. The ZFM structures an individual's access to different areas in the environment, the availability of different objects within an accessible area, and the ways the individual is permitted or enabled to act with accessible objects in accessible areas. Within a classroom context the ZFM for students is fashioned by environmental constraints such as the existence of technological resources, or time pressures exerted by curriculum and assessment requirements; by the particular learning experiences provided or materials or devices available; and the "rules" by which the classroom is run. While the ZFM has inhibiting or enabling properties, the ZPA is oriented to facilitating the achievement of new skills. Being teacher designed it directs access to sets of activities, objects, or areas in the environment in respect of which individuals' learning is being promoted. Both the ZFM and ZPA are thus culturally determined, and can be loosely associated respectively with means and ends. A link between the ZFM and ZPA is provided by the ZPD. For learning to be possible the ZPA must be consistent with an individual's capacity to learn (ZPD), while for the intended approach to learning to have a chance of success the ZPA must lie within the effective ZFM.

Turning to the consideration of teacher professional development the ZFM can be interpreted to represent environmental constraints, such as resource availability or curriculum and assessment requirements, which limit freedom of action and thought. Research on technology use by mathematics teachers has identified a range of factors influencing uptake and implementation that could be viewed as elements of a teacher's ZFM. These factors include: previous experience in using technology; time and opportunities to learn (pre-service education, professional development); access to hardware, software, and computer laboratories; availability of appropriate teaching materials; technical support; support from colleagues and school administration; knowledge of how to integrate technology into mathematics teaching; and beliefs about mathematics and how it is learned (Fine & Fleener, 1994; Manoucherhri, 1999; Simmt, 1997). While the ZFM suggests which teaching actions are possible, the Zone of Promoted Action (ZPA) represents the efforts of a teacher educator, supervising teacher, or more experienced teaching colleague to promote particular teaching skills or approaches. As with student learning it is important that the ZPA be contained within the ZFM, and is also consistent with the teacher's ZPD – that is, the actions promoted must be within reach if development of their identity as a teacher is to occur.

Some Examples From the Literature

We begin by noting how this theoretical approach may be useful in considering some situations described in the literature. Ramsden (1997) refers to "black box" functions, whereby students, at the touch of a button, can point and select rather than typing inputs in a *Mathematica* environment. He queries the educational worth of such approaches, arguing that learners are then less likely to achieve flexible mastery and use functions in creative ways.

One side effect is that we authors now have such control over everything, that, paradoxically, it's easier than ever before for us to take control *away* from the user.

Templer et. al., (1998) address similar concerns when describing the revision of a teaching program-again built around the use of *Mathematica*.

The most important alteration to the course came in the complete separation between course text and the physical areas (the *Mathematica* Notebooks) in which the students were to do their work. The text dealing with the mathematical background and experiments were to appear in paper form and the *Mathematica* Notebook screen was to be left entirely blank, awaiting the students' input. We felt that it was very important for each student to feel entirely in control of the computer screen. With our own text in the notebook, and patches where they were meant to contribute there was an ambiguity about where control over textual input and mathematical execution actually lay. With the new format we felt the distinction would be very clear. We also felt that forcing the student to type in all the input was important - it would force action on the students' part and hopefully avoid the mindless pressing of buttons with pre-entered code, which had occurred in some students during the trial. We also felt that having textual materials on paper is in fact more convenient to use for a student. You can flick backwards and forwards much more easily than you can screen.

The authors observed an interesting reaction to the use of automatic processes by the students. They noted that typically having mastered the rudiments;

> the majority of students began to hurtle through the work, hell bent on finishing everything in the shortest possible time.

The following comment, or a close relative, was noted as occurring frequently among the students, often in an accusing tone:

> I just don't understand what I'm learning here. I mean all I have to do is ask the machine to solve the problem and it's done. What have I learned?

From a zone theory perspective we can identify tensions between the ZFMs and ZPAs in the learning situations. For Ramsden the *Zone of Promoted Action* is focussed clearly in intellectual engagement including creative exploration using technology, while the 'black box' elements of the environment, act as inhibiting components of the *Zone of Free Movement,* constricting opportunities for such action. He draws attention to the power that a teacher has in restricting choices and opportunities of students, by prescribing too closely, what we are here calling the Zone of Free Movement. Templer et al., problematise the role of mediums of instruction as well as the intellectual aspects of learning. An earlier trial had effectively forced students towards exclusive use of a computer and away from mediating or indeed complementary opportunities provided by the use of pen and paper resources in parallel with the computer. The reasons are elucidated clearly in the extended excerpt quoted above. In terms of zone theory we identify a recognition that the ZFM provided by the original instructional context (computer only), was inhibiting to a degree in constraining students from the flexibility necessary to promote the desired activity (quality intellectual learning). In this case the incompatibility was recognised and addressed in the course revision. The student comment adds another useful dimension in illustrating that students themselves (if given the opportunity) are able to assess whether a learning environment provided is appropriate to support their learning. In this case they recognised that the zone within which they were required to function would not provide sufficient support for the understanding required of them. Such feedback, when recognised, provides a means of reviewing and revising instructional designs so as to enhance the compatibility of means and ends. What zone theory contributes is a structure and vocabulary to make these features explicit, and thence a capability to add analysis and inference to what otherwise tends to be anecdotal observation.

Zone Perspectives on Classroom Learning

We refer to a research study that has involved the activities of several participating teachers in three secondary schools in Queensland, Australia. All involved using technology in the teaching of senior secondary level mathematics, and regular videotaping of lessons took place over a two-year period. In the section of the Study described here we interpret learning-teaching-technology connections that occurred during two episodes, using the zone concepts described above.

In the first example the teacher admits minimal expertise in using a graphical calculator, but calls on a recognised student "expert" to demonstrate calculator procedures via a viewscreen. He retains control of the lesson agenda through the medium of the student presenter -- often to the extent of providing the mathematical commentary and explanations accompanying the student's silent display. The teacher maintains tight control on proceedings, and is reluctant to use technology to explore mathematical territory that is unfamiliar or outside the immediate lesson topic. Here is an edited extract from a lesson in which the teacher (Brian) introduces his students to the use of graphical calculators.

Brian: Do not turn on calculator until directed to do so and do only what I ask you to do. If you get lost following the OHP demonstration unit raise your hand immediately. (Now demonstrates procedure for clearing screen)

Brian: Is your screen the same as mine? *Hands up, yes. Hands up, no. Hands up, I haven't done it* yet? (Demonstrates successive keystrokes needed to draw graph of $y = x^2$ which students copy, and then discusses outcome)

Student: Yeah, but you can zoom in … and find out stuff.

Brian: But to zoom in wasn't part of what we were supposed to be doing.

Effectively Brian's conceptions of the ZPA have caused him to constrain the scope of the students' ZFM restricting their capacity to address the topic using other approaches. Effectively he has set ZFM = ZPA. It is arguable that the students' ZPDs in this classroom are not fully exploited, and students itching to explore are precluded from doing so.

In another school a lesson type involves students working in groups, with graphical calculators plentifully available. They are free to collaborate with peers in pursuit of the solution of problems for which the graphical calculator is of material assistance in the mathematical processing required. In this second extract a group of students are working together to solve a problem involving an application of newly presented Leontif theory. Although routine for the experienced, it was a 'first' application for the students, and involved identifying and carrying out matrix transformations, as well as translation and interpretation of mathematics in context.

Helen: (to Nerida): What did you get for your inverse?

Nerida: (dejected) It tells me there's a dimension error, and I don't know why.

Edward: Did you get that? *(passing his calculator to Nerida so she can look at his working)*

Helen: *(also showing her calculator working to Nerida)* It should be that.

Nerida: *(comparing her working with the other two screens)* That's what I had!

Helen: So then you ...

Nerida: *(puzzled, comparing screens with Edward)* Is that what you have? It's exactly the same as mine!

Helen: Yeah, and you times that by 200, 200, 200 *down* (referring to demand matrix)

Nerida: (sudden insight) Oh hang on ... That should be *four* ... Oh God!

Helen: What did you do?

Nerida: I didn't do four 200s!

Helen: Oh you big dork! (Nerida and Helen laugh) You've only got three 200s! (referring to number of entries in demand matrix – there should be four rows, not three)

Nerida: *(chastened) God I'm a moron! (talking to her calculator as she presses buttons)* Second, quit. Now.. (re-does the calculation). (Asks Helen) - Did you get that?

Helen: *(inspects Nerida's screen) Yeah! (Nerida jumps up from her seat in delight)*

Edward: *(to Nerida)* Look at mine.

Nerida: **(**goes over to Edward**)** Did you get this? *(Edward holds both calculators up side by side, compares his screen with Nerida's.* Nerida pulls his hair when he deliberately hesitates in replying.)

Edward: (with cheeky grin) Yes!

Nerida: Thank you!

Here the ZPA is consistent with the student ZPDs and within the relevant ZFMs - in the sense that students have all the technological resources available and knowledge potential within their group necessary for success. The decisions they make and the way they choose to exercise freedoms available within their ZFMs is of interest here. There are three human collaborators, and three calculators that are integrated as key players in resolving the identified problem. Dialogue moves easily between mathematics and technology. The bold dialogue highlights the enabling team or partnership approach, in which human and calculator contributions are seamlessly merged.

Zone Perspectives on Professional Development. Lisa was an experienced teacher but a relative novice in the use of technology when she participated in a graphics calculator training program run as part of the research project. When reflecting on her initial professional development experiences in this field, her comments suggest that, for her, technology was her master, since she "got lost in the first ten seconds, and was really turned off so didn't touch them again for a while". After several more workshops she felt confident enough to use graphics calculators in her teaching, but only in a servant mode:

> *Lisa:* I was [using graphics calculators], but not confidently and not proficiently. Not really realising how much they improved the thinking. More just as a tool to do graphs and things.

The training program offered as part of the research study proved to be a turning point for Lisa as it emphasised the impact of technology as a *partner* in pedagogy rather than focusing on "pushing buttons":

> *Lisa:* It was out of that weekend that I really understood the impact that [graphics calculators] had on the pedagogy. Up to then I saw it as a tool to draw graphs and analyse statistics. But at that workshop, just one little thing from that workshop, how we were working in groups, and they explained to us how kids start trying to help. So when we were doing that we were grabbing somebody else's calculator and sharing our data, so it made the group work thing a whole lot better. And I really valued the part where we, as groups, we went out and used the overhead projector and we presented our information back to the group. So I just, I really started to see different ways of using it that I hadn't thought of before. So it really enhanced group work, it really showed me that you could do a lot more hands on stuff, the practical activity with the motion detectors. That graphics calculators are good for inspiring all those other good things in teaching, like the hands on, the group work, and really starting to think when we were fitting functions to the data. Really having to think and understand what the intercept and the gradient mean. We weren't just *doing*, we were really *understanding* at a higher level. I found that really powerful. Because I had thought that all they do is save you that boring part of maths.

Environmental constraints and affordances (ZFM) seemed to play little part in Lisa's learning, possibly because as Head of her school's Mathematics Department she had considerable autonomy in obtaining desired resources and in managing curriculum and assessment programs. Instead, the re-construction of her identity as a teacher can be understood in terms of the changing relationship between her goals and interests (ZPD) and the ZPAs offered by the professional development and training she experienced. The early workshops she attended were described as "off-putting", because the emphasis was on procedural aspects of operating the calculators and the mathematics presented was too difficult for participants to engage meaningfully with the technology. She contrasted this with the approach taken in the weekend workshops offered as part of this research project:

> *Lisa:* I didn't really feel super confident until I went to the workshop that you were involved in organising halfway through the year. And I think it was then, using a different brand [of calculator] and understanding the bigger concepts, rather than just pushing buttons. Because at the pushing buttons level you never really understand how they operate. And after that I was just so inspired. It was just tremendous to meet teachers that came from all over the State to share with them, and the fact that you were there and the real gurus of technology and maths were there, prepared to give up their week-end ... it was just the way we were treated ... It was just that whole valuing and that sharing and learning from each other, and just to realise that other people are out there. So that was really the turning point for me to say that this is really exciting stuff.

Thus Lisa seemed to find a professional development ZPA that matched her need to focus on pedagogical, rather than procedural, aspects of using technology, and acknowledged the potential for experienced teachers to teach and learn from each other.

Implications for Theory and Practice

Having considered illustrative examples we now consider how zone theory can be applied to the construction and analysis of teaching and learning episodes. On the one hand interacting zones may be used as lenses through which to identify and interpret mathematical, technological, and pedagogical attributes of lesson designs and presentations. As such they provide a means to conceptualise and communicate consistencies, inconsistencies, similarities, differences, opportunities, and logical extensions with respect to teaching and learning activities. Among other purposes they provide frameworks for enhancing the analytic quality of lesson observation and planning, and for principled evaluation of classroom segments in teacher education programs.

We assume that overall learning goals are consistent with the ZPDs of a student group and represent the intellectual purpose of the teaching endeavour. Teachers construct activities designed to promote active learning by students (ZPAs) to achieve these ends. These planned activities may or may not be consistent with the learning resources, both physical and intellectual, accessible to the students (ZFMs). For example the students' may lack access to resources of a particular type, the range of such resources may be restricted, or the ways in which students are permitted or enabled to access and exploit the potential of available resources may be curtailed. While the provision of classroom technological hardware for instance may be outside a teacher's power, s/he is in substantial control of the extent to which students are enabled to access the technologies that are available, and the ways in which they are permitted or enabled to work with them and each other. Our interest here is in examining the ZPA and ZFM together, as a basis for lesson design analysis or as a component of lesson evaluation.

In the context typified by the first classroom excerpt we note the frustration experienced by students who wish to utilise a property (for example, zooming) that is outside the teacher's prescription. The teacher assumes the role of authority and prescribes activities (restricts ZFM) to conform to a very specific zone of promoted activity-other calculator functions and other students are not part of this zone. By contrast the classroom for the second excerpt was constituted as a community of practice, where, in addition to proposing conjectures, defending solutions, suggesting alternatives, and formulating approaches to problems, students were encouraged to share resources, both physical and intellectual. A pedagogical 'rule' in these classrooms is "if you can't do it, find someone who can and talk to them". This represents a ZFM with maximum resource flexibility, and governed only by rules constraining behaviours to those appropriate to the task oriented setting of a mathematical community. In terms of lesson planning there is little commonality in these approaches beyond the fact that technology is used. That is, to use *tech* or *non-tech* as defining differences misses the mark, for the key differences lie in the approaches to learning, clearly differentiated through a 'zone' lens. How in the first case the capacity for students to go beyond the prescribed limits was curtailed, while in the second how the power of technology, in combination with other attributes of mathematical processing and pedagogical actions, enabled a zone of free movement that encompassed everything and more that was needed for the promoted activity.

Turning attention to teacher education, we can establish frameworks that serve to assist both in lesson preparation and evaluation. These purposes can be represented, for example, in terms of questions such as the following.

- Is the purpose of the lesson appropriate to the relevant student group? (Are the specific learning goals consistent with the ZPDs of the individuals involved?)
- Will the planned learning activities scaffold or otherwise contribute to the desired learning? (Is the planned ZPA appropriate to the relevant ZPDs?)
- Do the proposed strategies (including use of technology) provide opportunity for the approach to succeed? (Does the implied ZFM provide sufficient scope to enable the ZPA and more?)
- Are inconsistencies present? (Is the ZFM planned for the students inconsistent with, or unduly restrictive with respect to the needs of the ZPA?)

Clearly questions such as these can be used either for framing and evaluating planned approaches before enactment, or as a basis for evaluating and providing feedback on the conduct of lessons. Such an approach changes the currency from a consideration of lesson *events* – how technology, for example, was used and how effective it appeared to be – to a *structural view*, in which its efficacy is tested against a framework of zone-based theory. From this viewpoint two overtly similar actions with technology within different contexts, can represent quite different contributions to learning; while different uses (and indeed different technologies) can be identified with teaching-learning actions of the same genre.

The Case Study involving Lisa demonstrated how an experienced teacher developed that part of her pedagogical identity concerned with technology use, by negotiating changing relationships between her teaching environment, actions, and professional learning opportunities. Clearly, it is not possible to explain Lisa's enhanced appropriation of technology as being determined solely by the material and human resources available to her in the school setting or from professional development activities. Instead, the brief analysis presented here suggested that Lisa sought out professional development opportunities (ZPA) that would extend, rather than simply accommodate, her existing ideas about teaching with technology (her ZPD). In doing so she recognised the importance of an untrammelled approach, and the freedom to explore possibilities without preconceived notions of limits to particular forms of calculator usage (her ZFM). These observations in turn raise interesting questions for further research on how experienced teachers might develop their pedagogical identities as users of technology.

Zone theory represents just one approach to providing a perspective on observed and planned events, and on approaches in teaching – learning situations. It is however an approach that goes beyond description, in providing analytical tools to support the development of theoretically coherent and systematic frameworks to interpret, evaluate, and design actions.

References

Doerr, H. M., & Zangor, R. (2000). Creating meaning for and with the graphing calculator. *Educational Studies in Mathematics, 41,* 143–163.

Fine, A. E. and Fleener, M. J. (1994). Calculators as instructional tools: Perceptions of three pre-service teachers, *Journal of Computers in Mathematics and Science Teaching*, *13*(1), 83–100.

Goos, M., Galbraith, P., Renshaw, P., & Geiger, V. (2000). Reshaping teacher and student roles in technology-enriched classrooms. *Mathematics Education Research Journal, 12*(3), 303–320.

Guin, D., & Trouche, L. (1999). The complex process of converting tools into mathematical instruments: The case of calculators. *International Journal of Computers for Mathematical Learning, 3,* 195–227.

Manoucherhri, A. (1999). Computers and school mathematics reform: Implications for mathematics teacher education. *Journal of Computers in Mathematics and Science Teaching*, *18*(1), 31–48.

Ramsden, P. (1997, June). *Mathematica in education: Old wine in new bottles or a whole new vineyard?* Paper presented at the Second International Mathematica Symposium, Rovamiemi: Finland.

Simmt, E. (1997). Graphing calculators in high school mathematics. *Journal of Computers in Mathematics and Science Teaching*, *16*(2/3), 269–289.

Templer, R., Klug, D., Gould, I., Kent, P., Ramsden, P., & James, M. (1998). Mathematics laboratories for science undergraduates. In C. Hoyles, C. Morgan, & G. Woodhouse (Eds.), *Rethinking the Mathematics Curriculum* (pp. 140–154). London: Falmer Press

Valsiner, J. (1997). *Culture and the development of children's action: A theory of human development* (2nd edition). New York: John Wiley & Sons.

Wertsch, J. V. (1985). *Vygotsky and the social formation of mind*. Cambridge, MA: Harvard University Press