TEACHING AND LEARNING ENGINEERING DESIGN THROUGH ACTIVE SOCIO-TECHNICAL CONTEXTING

LicinioRoque[1]

Abstract *¾ Understanding teaching and learning as an interactive process through which language skills are built, the authors are experimenting new strategies to foster learning within the Software Engineering and Interaction Design disciplines. This paper reports on those experiences and on the role that contextual cues and the social synthesis of engineering situations may have played in the learning processes. We also analyse the role that educational tradition may have played upon students' expectations, reactions to novel situations and adherence to active learning models. The authors present a methodological framework for the advancement of learning experiences understood as socio-technical contexts where intellectual instruments are to be actively developed as integral parts of those contexts. This framework focuses on the synthesis of learning experiences through a process of co-evolution in a model of context (representing the disciplinary approach and possible learning trajectories) and on models of instruments representing the language or skills that are being developed within that context. As the skills fill the zone of proximal development within the context modelled, new contextual cues, instruments and challenges may be added to expand the development zone. This does not need to happen in a teacher-student hierarchical relationship, and may be managed as a multidirectional community process.*

Index Terms ¾ The role context in learning, active socio-technical contexting, Context Engineering framework, engineering education.

INTRODUCTION

In a seminal essay on "The Problem of Meaning in Primitive Languages", Bronislaw Malinowski (1923) elaborated two important themes that were to figure prominently in the study of context: 1. that language is embedded within a context of situation; 2. that Language must be conceptualised as a mode of practical action. Such a perspective on language as "an indispensable element of concerted human action" led him at a later date to articulate a view of meaning as something embedded within trajectories of action and the word as a means of bringing things about, a handle to acts and objects. He also told us that "Meaning... does not come... from contemplation of things, or analysis of occurrences, but in practical and active acquaintance with relevant situations. The real knowledge of a word comes through the practice of appropriately using it within a certain situation."

What this anthropological text means to the study of the engineering activity and engineering education can only begin to be grasped once we actively search for the role played by context, or the lack of it, in communication and learning. This does not mean that the authors believe that engineering disciplines resemble primitive languages, but, if Malinowsky is right about the conditions upon which one truly understands the meaning of words (or disciplinary utterances), then we must question ourselves about the impact of the situations we create in our educational practice and the meanings they contribute to. If the situation is indeed essential in the construction of meaning, then what meaning has the "content pouring" metaphor?

Understanding teaching and learning as an interactive process through which language skills are built, the authors are experimenting new strategies to foster learning within the Software Engineering and Interaction Design disciplines. This paper reports on those experiences and on the role that contextual cues and the social synthesis of engineering situations may have played in the learning processes. We also analyse the role that educational tradition may have played upon students' expectations, reactions to novel situations and adherence to active learning models.

From Content Delivery to Context Management

We explain the motive of our change attempts on a growing perception that we need to change our perspective from a content delivery metaphor, in part sustained and reinforced by cognitive models of behaviour, to a context management metaphor where the teachers role is more akin to that of a coach or facilitator than that of a preacher.

Several authors have reflected on the special character of design activities, on several fields, from Architecture to Engineering. Alexander [1] talks about the search for a solution as a process of fitting diverse factors within a professional language. Schön [8] talks about reflection-in-action as the essential character of any design activity, the "conversation" that the professional establishes with the situation. How can a student of Engineering Design learn to exercise this dialogue except from immersing herself into this kind of situation? For a long time this has actually been the case. The students learned about the techniques of their peers, what they were, when to invoke them and some of the risks involved, but she only got first hand experience with them when on the (first) job. Enterprises even developed a folklore about how to treat trainees for the "real job", meaning that, somehow, what the newly licensed person knows is "less real" than what it takes to do the real job. We

[1] Licinio Roque, University of Coimbra, Informatics Engineering Department FCTUC, Polo II, 3030 Coimbra, Coimbra, Portugal. lir@dei.uc.pt

suspect all this social discourse around the formative capacity and deficiencies of higher education may have something to do with the dominant perspective: that of delivering static content to the vessels. We also speculate on the socio-technical reasons why we may have evolved into this situation, namely: the scalability of teaching for the masses versus the perceived higher cost of individualised learning experiences, the culture of passivity present in the students relationship to the system favours a teacher directed model and is reinforced by it, a wages policy that does not encourage risktaking by teachers or the search for novel learning approaches, the normative and legislative frame that limits innovation of teaching methods, the availability and market forces behind content delivery technologies, low investment into methodological training of teachers.

We think that the content delivery metaphor tends to focus on the "know-what" and does not deal much with the "know-how". That seems to be left for training. Curiously enough, training, especially on-site contextualized training, have been studied under the Communities of Practice [3] [11] framework that focuses more on the social and peer to peer dimensions of the learning experience than on the delivery of specific contents. Attention is dedicated to the study of the contextual conditions that enable learning and not so much on the processes for delivering information or knowledge. Leaning is then viewed as personal construction based on the social experiences at hand, whereby the learner becomes a competent member of society or a group, sharing language and other instruments. This view as a long track of subscribers, (with variances,) from Vygotsky [9,10] to Piaget, Polanyi [6] and others. All recognising the importance of the social dimension present in the learning experience, although sometimes disagreeing on the matter of process. We too, as teachers and engineering professionals need to recognise this dimension and effectively address it in our models and practice.

In dealing with this perspective we were informed by Activity Theory concepts such as Vygotsky's Zone of Proximal Development [9] and Engeström's expanded model of the activity and expansive learning model [2]. The Zone of Proximal Development is an alternative to the levels model of learning progression that are typically centred on the subject matter being learned and not on subject as performer of the learning activity. Vygotsky demonstrated that while two persons may be at the same development level when we evaluate what has been learned they may have different Zones of Proximal Development, meaning what they can do with the help of a more experienced person may actually differ. This leads to the conclusion that their development possibilities can be different and recognising that should possibly better direct us in our development efforts, as teachers. While developing

Engeström elaborated on the original mediation based Theory of Activity to provide an expanded model, where he added explicitly the element of Community and considered the three resulting mediating relations in human activity. These three mediations being: a) the instrumental between the subject and object (the original notion); b) the social, between the subject and the community, and the organisational (or division of labour), between the community and the object of the activity. With this model he managed to reconceptualize leaning in relation to the development and acquisition of these mediators that takes place in social settings. As a subject dwells with the roles and practices of a community she builds relationships to the instruments of that community, and vice-versa, becoming a competent member. This building of relationships may be interpreted as the development of the individual's functional organs (mental representations) that enable her to perform the desired activities and become a competent member of the community of practice.

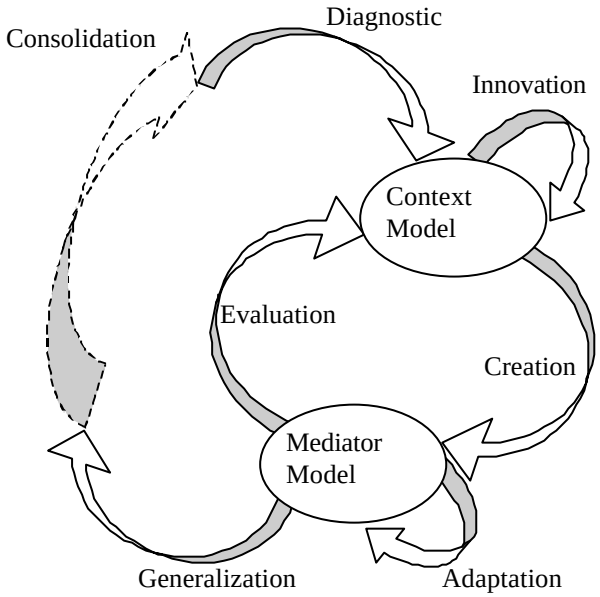
As teachers of engineering, we must acknowledge the interrelations between the diverse forms of mediation, instrumental, social, and organisational, and learn to deploy learning experiences that enable their development by the students as an integrated ensemble, each mediation fostering the others, as a traversal on the student's Zone of Proximal Development. With this notion in mind we must devise and deploy contexts, that is activities, that enables the student's own build-up of relations with the object and community of practice. This poses very different problem from the content metaphor. How can we design activities as contexts for learning, if that process is viewed as open-ended? Can we direct what learning occurs in any way? How do we make sure that learning actually occurs? How do we measure or certify it?

Engineering the Context of a Learning Experience

While managing the learning of Software Engineering techniques (mainly those typically associated with analysis and design phases) and Interaction Design (the from scenario analysis to product development and software usability testing) we begin experimenting with the idea of adapting a framework we initially developed for problem redefinition as part of dealing with context within information systems development. While performing that research we developed the following framework that explicitly relates our views upon the context that is our target with the models developed for the mediators of the intended change. With its focus on context, the framework divides our development concerns into six main activities (diagnostic, innovation, creation, evaluation, adaptation, and generalisation) and a consolidation phase. When interpreted as the basis for a method to manage contextual change, these activities may be understood as six movements or "operators" to be juggled in a planned or in contingent form. Either way, the main contribution of this framework may be that of bringing to the fore the importance of our explicitly dealing with contextual factors influencing our development situation.

Adhering to this framework's perspective upon development, now of learning experiences, we initiated a

change trajectory that we sough to lead us to a point further from the content delivery and closer to the context management metaphor. We went through four years of reflection and re-enactment of our role as teachers as well as the adaptation of the goals and instruments of our practice within those disciplines. This effort coincides with and is partially informed by an adoption of a socio-technical perspective for the study of our activities as designers and by the social-cultural-historical perspective followed by Activity Theoretical constructs and methods.



A CONTEXT ENGINEERING FRAMEWORK [7]

We will proceed by reporting on our methodological approach to the current discussion. We start by performing a diagnostic, producing a context model that will be object of innovation attempts. We propose some innovations and design interventions to mediate desired contextual change trajectories. These interventions may take various forms and be artefactual, normative, procedural, or simply verbal utterances at particular times. We deploy those interventions and evaluate their results in comparison to desired context model. Some of these interventions as deployed on a micro-cosmos, e.g. a subset of the tasks or people involved in the larger learning experience. When this is the case we try to learn what we can do to adapt that intervention and generalise it to the whole community (or the next years). As this rough "process" unfolds we will need to manage the consolidation of the desired trajectories on the context, that is, that needed learning takes place and can be validated by actual learner's experience and reflection-in-action.

A DIAGNOSTIC OF OUR PARTICULAR CONTEXT FOR LEARNING ENGINEERING DESIGN

In a brief diagnostic of our particular context, while teaching design related subjects in engineering disciplines and other general aspects, we recognise a set of socio-technical factors:

- Classic Theory-Practice separation of concerns is mapped on the organisation of curricula into theoretical and practical classes.
- Normative distribution of time decided on the basis of work distribution among faculty and not of process needs: 3 weekly theoretical hours plus 2 weekly practical hours, aprox. 15 weeks semester.
- Relative liberty for the teacher to adopt any strategy seen fit to teaching and learning needs, and to use the lecture time as she sees fit.
- Theoretical program rules over the practical program, which is subsidiary to the point of mere illustration or exercise of theoretical subjects.
- Dependence on the teacher's normative influence, with a majority of students just trying to follow the leads and not directing their own learning.
- Normative need to map whatever evaluation scheme to the 0-20 value scale.
- Students evidence a passive attitude enforced over 12 years of basic and secondary courses.
- Practised evaluation over basic, secondary and higher courses invariably ignores collaboration as an important human competence and favours independent work, repressing all co-operations as normative violations.
- Evaluation mainly (over 75%) based on written exams favours a "know-what" approach, aligned with theoretical learning objectives.
- Attempts at a more practical learning approach based on work-sheets to be developed on 2 hour assisted classes favours specialised or isolated tasks and does not seem inline with integrative learning goals.

These are some of the factors that effectively format the context within which we begin, every year, our learning interventions. Some of them are quite difficult to overcome and undermine or significantly resist any attempt of adopting an active leaning approach. So, for the last three years we begin considering them a change target along with the "normal" subject related learning goals.

POSSIBLE INNOVATIVE TRAJECTORIES

In order to loosen the grip of our traditional teaching-learning content metaphor we begin envisioning what would be a sufficient context for enabling the kind of learning activities that we, at the time rather instinctively, considered more appropriate for learning design related subjects. We considered this goal while fitting within the established normative framework provided by legislation and internal rules. We went for some changes that were on our direct reach:

- A prominent role for practical classes setting their own agenda. The practical semester evolves along an integrated exercise that provides opportunities for enacting the use of the instruments that are part of the

learning goals. The use of these instruments is illustrated using class time and the main exercise is performed on the student's self-directed time, while consulting with the teacher whenever necessary.

- A parity role for theoretical classes as conceptual frames of practice, either presenting established instruments or discussing and framing practical events.
- A more prominent role for student self-directed activities, based on description of learning goals and possible learning activities.
- Promoting collaborative learning and performance through: a) free exchange of reusable components or results of others when effectively integrated with their own work; b) joint performance of activities.
- Effectively valuing practical activities on evaluation, equal or greater than 50% of total.
- A change of focus on evaluation towards the performance of activities and not their product. The product of the activities is a validation of performance.
- Self-reflection on the performance as an important evaluation element. Normatively, the students have to explain their performance and classify it as to its nature, importance, results and learning goals.

With this agenda we begin considering the way to intervene and try to bring about the desired changes. At this point it is important to note that the subjects curriculum remained essentially the same, all we seek to operate on were the contextual factors that we perceived to be influencing the achievement of learning goals, both qualitatively and quantitatively.

THE HISTORY OF INTERVENTIONS

During the last three years we managed to "experiment" with these ideas trying to validate some new forms of learning activities and mediators for the Interaction Design discipline a second semester (February to May), second year (now changing to the third) course, with around 100 students.

First Approach

On the first year we attempted a simple change that consisted of the adoption of a "long term" project exercise (to our standards, during an entire semester) with the introduction of a 50%/50% distribution of the evaluation between written exams and practical work. The exercise was specified on the basis of an elementary set of requisites to be fulfilled by the resulting artefact. Any other requisites were to be developed by the students as part of the exercise. A minimum and maximum number of students per working group were also specified (2-4) and some ground rules as to what could or not be exchanged between workgroups. A deadline was established at the end of the semester. During classes we verbally emphasised the importance of using the techniques that were being covered on the classroom, on the practical exercise. The evaluation model for the exercise was kept undefined until delivery. After the delivery date the students were called to make a public presentation of their work for their colleagues. The presentation was interpreted by the teachers as an opportunity to sell their work and put to evidence their subject learning achievements. Most students did not share that perception.

The workgroups distributed themselves through the five themes proposed and work was realised with minimal teacher's intervention. Possibly due to the temporal distribution or programming of the subjects along the semester, most students focused on programming tasks and arranged for a "cosmetic treatment" of important disciplinary topics like usability evaluations. Most workgroups begin the exercise very late (one week or less from the deadline) and ended up entangled in messy debugging sessions, distracted from the central subjects of scenario, task and user analysis, interface design and prototype evaluation. And it showed up in the presentations they did of their work.

Evaluation

When we reflected on this experience we recognised a set of contextual factors influencing the experience and a set of indicators that still showed continuity with the previously criticised context. The learning activities were greatly influenced by extra-academic events like the Easter holidays a local student's feast (Queima das Fitas) that cut the semester in three very distinct temporal segments. There is a set-up and a let-go time associated with each specific temporal segment that leaves around 9 effective weeks from the 15 academic calendar weeks. The progression of the exercise was very low in the beginning of the semester, reinforced by the students' attention diverted towards other competing subjects with more frequent deadlines (on a weekly basis). Most students have low experience organising their work on a semester long project, as this is the first that the students have to develop in those conditions. We observe that most students have difficulty managing their own learning goals and frequently ask about how we want them to do the work and the relation to their evaluation. Some of them are so concerned with the final evaluation that all they want to know is how they are going to get their grades.

Second Year Adaptations

For the second year we adapted the exercise, giving it increased value 15/20 in the final grades. We took into consideration the reflections on the first year run and introduced some additional forms of mediation. In order to try and circumvent the impact of time slicing and help students distribute their work along the semester we decided to introduce two additional deadlines immediately before the Easter and the Student's Feast interruptions. I order to help students self-orientation we created an extensive normative document that specified the kinds of activities that they were supposed to perform while letting them arrange those activities as they see fit. The proposed activities were

directly linked to specific techniques that were being exemplified along the semester on the practical classes. A self-grading table was given so the students could relate the performance of every member of the workgroup to the rate of participation and achievement of the activity's goals. There was only one theme and the work package was substantially larger (developing a UML design tool) thus requiring the effective participation of 4-6 elements within the team. Inter-group co-operation was proposed and promised to be positively valued. In fact it was stated as a requirement for the exercise. We intended for this to enable the development of communication and collaboration skills while constituting an opportunity for them to exercise the communication tools that were part of the learning goals.

A Different Kind of Evaluation

This new form of the exercise enabled yet a fundamentally new approach to evaluation. We intended the students to self-evaluate and accept those evaluations with "normal" corrections. Additionally, that evaluation was based on activity performance and learning statements. The object of the work, in this case a tools for UML visual design was subsidiary and served the purpose of validating the performance, so that if you tell a good story it must somehow be reflected on the product. But you may produce a bad product and have a wonderful story. However you may have a troubled story and a troubled product to go with it and be able to demonstrate that you have learned a lot. That is as valuable if not more than telling wonders all around. And this is a substantially different characteristic from the traditional way to demonstrate success in the content centred paradigm.

Yet the students (?) resisted this new form of evaluation. They go as far to avoid it as to ostensibly manipulate the figures to give the same grade to everyone on the workgroup or to makeup a desired final result. Resorting to the Actor-Network Theory lingo [4,5], the social network where this exercise takes place resisted the inscription of this new actor. Mentalities, cultural factors that define school and the established how-to and meaning of evaluation all seem to be against self-evaluation based on self-reflection on the activity. In fact we often wonder how a lot of students manage to reach learning goals when they so often show signs of ignorance of those goals. But if we carefully analyse the dominant paradigm we can build a quick explanation: the alignment of social actors on the content pouring context model is such that the student is relieved of the hard task of directing his own learning. That is an acknowledged task for the teacher, which comes with the superposition of the legislative and judging roles. Of course there are students that able to get past this, but we are still at hands with the problem of creating instruments that enable all the students to self-direct their learning.

We have an additional problem since we do not have precedence between courses we have students that are not prepared to take this subject, for instance because they do not have sufficient programming skills. That could explain a rate of 30% early dropouts and 10% last minute excuses for projects delivered as insufficient kludges that could not have been through the desired process. On the other hand those that manage to successfully deliver, in general do good work, and thus apart from the drop-outs we have few low grades. When the students are ill prepared they tend to focus their attention on the source of their troubles (in this case, programming) and miss the prime subject of the exercise (design and evaluation). That shows up on the results, as prepared students, in general, dedicate much more effort towards evaluating and perfecting their projects.

The three deadlines worked out, making the students aware of the challenge earlier but not so much as we would expect as many of them were frequenting parallel programming classes and were leaving implementation to the last minute. The size of the team proved to be exaggerated and enabled a lot of "bystanders" as they organised within teams with a strict division of roles one or two implementers some designers and other evaluators. Usability testing is still a problem as many of the teams arrive late at a prototype stage where they can effectively evaluate and miss the opportunity, performing (or faking) the tests among themselves.

We still need to work on a better stimulus for co-operation! As surprising as it may seem, the large majority of students doesn't grasp or don't take the opportunities for collaboration. It is seen as a problem. We suspect, despite of our frequent recommendations that the students think that to be some kind of misbehaviour. May they don't think it is fair for others to take advantage of the product their work? Maybe they think their competition for higher grades justifies secrecy? Maybe it is troublesome? Maybe they don't have the time for co-ordination? Maybe they ignore the opportunities, since they spend the last days in relative isolation? We even tried offering to discriminate positively on the basis of co-operation attempts. We have yet to tackle this subject and deploy adequate mediation or motivational forms.

Third Year Adaptations

We decided on letting go of a lot of the extensive regulation and go for a better communication attempt of the learning goals and opportunities. We simplified the kinds of activities, making use of the Context Engineering framework as a model for them to organise their work and report it. So, we ended up with six categories of activities (or methodological problems) and tried to situate the teaching of techniques as solutions in that framework. We them simplified the obligations to that of every member of the team performing at least once every kind of activity in whatever form, as presented or worked out on their own. We reduced team size to 2 elements and explained that they could use each others work (inter-teams) as long as they made explicit reference to it when reporting their activities. We simplified the reporting model (a Word template) for the

activities. We defined the work package as simple as we could: "to develop an email application to run on a device that has a 200x300 physical display". They had to envision the market and make any choices accordingly to the conditions they saw fit to it.

We intended the task to be demanding and eventually requiring more than each team's abilities. The target was intentionally ill specified and left to interpretation. The development platform was the choice of the students but most of them would chose JDK 1.3 with which they were more familiar. Sharing the platform could foster code exchange and knowledge reuse (for instance, how-to program a certain thing or behaviour).

For the first delivery we asked for a non-working demo of the application. For the second delivery we asked for the first working prototype. For the third delivery we asked for a second and revised version of the prototype. Noting that in the precedent years their was a reluctance to produce adequate reporting of the activities we now asked them to be delivered with every product version in accordance with the activities performed to get there. The reporting was made in electronic form, updated with every delivery.

Re-Evaluation

Finally we got some co-operation between teams. A particular troublesome part of the work package (communications with an email server) aligned with smaller teams seemed to provide the opportunity for co-operation. Additionally, some of the teams managed to create demos that they used for early testing with other colleagues and friends (although still not dispensing great attention to proper test formulation). An anticipation of the explanation of testing methodology in classes (used to be a later subject) may also have raised more awareness and opportunity that in previous years. Many teams still have difficulty dealing with the subject of usability testing. We think they don't feel good about showing their work publicly or even to friends. Possibly a problem of self-esteem or undervaluation of academic work.

We still have a recurring problem we self-direction and evaluation based on activity reporting: new students still insistently ask for the evaluation goals and try to get a more precise definition of expected performance.

SOME REFLECTIONS

Managing the Learning Experience

As we see it we have been managing the learning experience for a community of learners. This is akin to community caretaking whereby it is necessary to set-up a carefully tuned exercise and permanently engage into activities to keep it going, feeding the learning process at the right time and in the right proportion. You need to tune the exercise normatively, to get a network of factors enabling the development of the activities that, you suspect, will provide opportunities to achieve the learning goals. If you work from a social context akin to ours you will need to explain a lot and develop socio-technical instruments (techniques, rules, and procedures) aligned with learning goals and that can successfully integrate with or challenge known factors already present.

Validating learning

We are yet far from achieving the emergence of true active learning. Our experience still reveals the need for a lot of intervention in the context to bring about the desired student development. We think we have got a lot co-operation from students and when that happens it is so obvious that we have little effort to grade them (they do it themselves). When we suspect we are being told a nice story we feel that we have fallen to the old paradigm and we grade accordingly. In fact, is a student is able to tell a nice consistent story you are in effect in the presence of a phenomenon that resembles perfectly the written examination. A student who is able to make the nice story is a good performer in the content pouring paradigm.

ACKNOWLEDGEMENT

We acknowledge the opportunity provided by our institution and to our students, who embraced the challenges.

REFERENCES

[1] Alexander, C. W. , *Notes on the Synthesis of Form* , 1970.

[2] Engeström, Y. Learning by Expanding: An Activity-theoretical approach to developmental research, Orienta-Konsultit Oy, Helsinki, 1987.

[3] Lave, J., Wenger, E., *Situated Learning: Legitimate Peripheral Participation (Learning in Doing: Social, Cognitive and Computational Perspectives)*, Cambridge University Press, 1991.

[4] Law, Hassard, editors, *Actor Network Theory and After*, Blackwell Publishers, 1999.

[5] Law, J., *A Sociology of Monsters: Essays on Power, Technology and Domination*, Routledge, 1991.

[6] Polanyi, M., *J Personal Knowledge Towards a Post-Critical Philosophy*, University of Chicago Press, 1974.

[7] Roque, L., Almeida, A., "The Context Engineering Framework", Proceedings of 4th ICEIS - International Conference on Enterprise Information Systems, Vol 2, 2002.

[8] Schön, D., The Reflective Practitioner : How Professionals Think in Action, Basic Books, 1983.

[9] Vygotsky, L. S., 1978, Mind and Society: the Development of Higher Mental Processes, (edited by Cole, M., et al), Harvard University Press, Cambridge, Massachussets, 1978.

[10] Vygotsky, L. S., 1986, Thought and Language, (revised and edited by Kozulin, A.), The MIT Press, Cambridge, Massachussets, 1986.

[11] Wenger, E., *Communities of Practice: Learning, Meaning, and Identity*, Cambridge University Press, 1991.