

Contexts for questioning: two zones of teaching and learning in undergraduate science

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Abstract Higher education institutions are currently undertaking a challenging process in moving from teacher-orientated to student-focused approaches. Students' ability to asking questions is fundamental to developing critical reasoning, and to the process of scientific enquiry itself. Our premise is that questioning competences should become a central focus of current reforms in higher education. This study, part of a broader naturalistic research project, aims at developing a theoretical framework for conceptualizing different contexts for questioning, illustrating the application of the proposed framework (contextual questioning zones) and reflecting about some of the dimensions of teaching and learning, for overcoming some of the challenges that higher education institutions are facing presently. The discussion of two 'opposite' contexts of enquiry is based on qualitative data, gathered through close collaboration with four teachers of undergraduate biology at a Portuguese university. These teachers were observed during their 'daily activity' during an academic year. Data was also gathered by interviewing these teachers and 8 selected students, at the end of the year, and used to sustain the argumentation. The paper concludes with some reflections and suggestions to promote authentic enquiry-based learning experiences.

Keywords Undergraduate teaching · Learning · Contexts for questioning · Biology

Introduction

This paper reports on the ways university teachers use questions during lectures, and how students perceive and react to the teaching–learning contexts that are created by those reactions.

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The broad context of the work lies in improving teaching and learning in higher education, in this particular case within undergraduate sciences at a major university in Portugal. While Graesser and Person (1994) maintain it is '*well documented that student questions in the classroom are very infrequent and unsophisticated*' (p. 105), other studies indicate that learners actually *do* have questions but, in general, avoid asking them (Dillon 1998; Watts and Pedrosa-de-Jesus 2005). The reasons for this avoidance are complex (Watts and Pedrosa-de-Jesus 2007) and largely hinge on the confidence students have that their questions will be well received and taken seriously by teachers. Throughout the paper we have a clear preference for redressing a perceived broad imbalance, our main argument being that a lack of interest and engagement in student-centred learning may be visible symptoms for deeply rooted causes, long-standing personal and social values in the academic community that hinder current innovation efforts of universities. By explicating two broad environments to teaching-through-questioning, it may be possible to broach possible contextual issues surrounding teaching and learning, and mitigate some of the perceived difficulties with these.

So, do teachers actually welcome students' questions? Rop's (2002) work suggests that teachers are ambivalent at best, they commonly listen to a student's open curiosity with contradictory feelings: the need to 'honour' a student's question, give students time and patient support in their struggle to understand content, all of which is then weighed against the seemingly incompatible need to maximise 'teaching time' and 'cover the content of the course'. Less compassionate, though, is when teachers perceive student questions as annoying, an impediment, overbearing and a test of patience, particularly when they arrive too frequently or seem set to challenge received 'curricular wisdom'. These different teacher attitudes impact upon the ways questioning is encouraged or discouraged during class time. In this paper, we are concerned with such 'micro-politics' of ('real') classroom life.

This paper first set out two deliberately dichotomous 'contextual zones for questioning' that we call Zone 1 and Zone 2, and draws upon literature in learner-generated questions and teaching approaches. Second, the model is used to discuss some illustrative qualitative data gathered in the context of a broader naturalistic research project. Data from four teachers and students undertaking two semester-long modules in life sciences are discussed, being focused on their experiences of classroom questioning. Finally, the paper concludes with reflections and suggestions on constructivist classroom contexts and cultures, and on ways that teachers can manage or, in our terms, can orchestrate learners' questioning within the flow of a session to enable authentic enquiry-based learning experiences (Watts and Pedrosa-de-Jesus 2005, 2007).

Questioning practices and approaches to teaching

Portuguese higher education institutions are undertaking a challenging process in moving from a teacher-oriented to a student-focused approach (Veiga and Amaral 2009). This greater emphasis on a learner-centred vision of university teaching demands that students' academic autonomy be the outcome of well-planned educational experiences to help all students develop independence (Biggs 1999) and become critical questioners (Ironsides 2003). According to Chin and Osborne (2008), this ought not be unusual, instead it should be a key feature of academic scientific discourse and, from this standpoint, questioning is central to eliciting explanations, postulating theories, evaluating evidence, justifying reasoning and clarifying doubts. Thus, our central premise is that the act of questioning can lead learners to engage in critical thinking and reasoning. Given that asking questions is

fundamental to science and scientific enquiry itself, the development of students' abilities to ask questions should, therefore, become a central focus of current reforms in higher education. We argue (Watts and Pedrosa-de-Jesus 2005) that question-asking is a key component to a learner's 'enculturation' into the patterns of understanding, language and thought, critique and debate that are characteristic of academic disciplines. In our view, this is maximised where university teachers create positive learning climates for questioning (Pedrosa-de-Jesus et al. 2004).

There is a body of research to support the argument that most 'teachers teach the way they learn' (Mazur 2009; Stitt-Gohdes 2001). Since many university teachers have experienced academic success within instructor-centred environments that relied heavily on teaching-as-lecturing, it is understandable that preferred styles of teaching, at least initially, would be to repeat 'what worked for them.' Typically such teachers' behaviours would reflect the beliefs and values they hold about the learner's role in 'knowledge exchange' (Heimlich and Norland 2002), would be content-oriented and prefer to use formal teaching methods, favouring less student involvement, questioning, and more structured class activities (Hayes and Allinson 1997; Pithers 2001). On the other hand, classroom teachers who are skilled in principles of adult learning or science education research (Andrews et al. 2011) and have experience with student-centred learning and constructivism are more likely to adopt broader approaches to teaching (Stitt-Gohdes et al. 1999; Pedrosa-de-Jesus and Silva Lopes 2011). Typically, such teachers would have broad views of how teaching can occur and strong beliefs about the need to engage learners' questioning in the learning process. They would be aware of the changing demographics of classrooms and the influence of technology on students' ways of learning (Glenn 2000; Stitt-Gohdes 2003). They are more likely to substitute self-directed learning opportunities and interactive learning environments for the traditional lecture and make use of '*varied resources to create personally meaningful educational experiences*' (Glenn 2000, p. 14). They would have understanding of the shifting balances of authority within the classroom as students assume greater responsibility for their own learning.

Despite the general confusion in definitions of 'teaching styles or approaches' research (Devlin 2006; Meyer and Malcolm 2006), the identification and description of relevant teacher characteristic has revealed to be useful in the effort to understand the complex dynamic of the teaching–learning processes (Pedrosa-de-Jesus and Silva Lopes 2011). Therefore, in this work we used the revised Approaches to Teaching Inventory, or ATI-R (Trigwell et al. 2005) an instrument developed for higher education contexts, in order to identify and describe teachers' main teaching and learning concepts, as well their main teaching intention. Inventory results were then complemented with other type of data, namely classroom observations and also individual interviews to each teacher (Pedrosa-de-Jesus and Silva Lopes 2011).

The inventory was developed by Trigwell and co-workers who describe two qualitative different teaching approaches (PTAs) called: 'information transmission, teacher-focused'—ITTF, and 'conceptual change student-focused'—CCSF (Trigwell and Prosser 2009) Table 1 sums up the main differences.

With the permission of these authors, the ATI-R was translated to Portuguese, and then, for validation, translated back to English. The Portuguese version was posted on the university website with an e-mail inviting all teachers, across all subject areas, to participate (n = 890). Ten per cent completed the inventory and the reliability measures revealed internal consistency for both scales of the Inventory, with Cronbach alpha over 0.75. (ITTF—0.83; CCSF—0.86). For the purposes of this paper we focus on four lecturers who teach undergraduate microbiology and evolution, two identified as being ITTF (Teachers 1 and 2) and two as being CCSF (Teachers 3 and 4). We arrived at these designations through

Table 1 Preferential Teaching Approaches (Trigwell et al. 2005; Trigwell and Prosser 2009)

	Teaching/learning concept	Teaching intention
ITTF	Teaching is the transmitting of information (“teaching-by-telling”)	Students acquire the contents of the discipline and are able to connect them and fulfil test requirements
	Learning is the accumulation of information with the aim of accomplishing external demands	
CCSF	Teaching is to support students in developing and changing concepts	To help students to construct their knowledge by confronting and changing their perceptions of the concepts
	Learning is developing and changing concepts	

working closely with all four teachers during an entire school year, namely by observing their lectures, through their responses to the ATI-R and to the semi-structured interviews. The teachers and students were briefed at the beginning about the nature of the research and were therefore sensitised to the issues surrounding classroom questioning.

The lectures on microbiology and evolution took place during the first and second semester, respectively, and were organised in groups of 40 students. Each group had a 2-h lecture once a week for each discipline. Three of the collaborating teachers lectured in microbiology, each one being responsible for teaching one-month modules to three groups of forty students ($3 \times 40 = 120$ students). From these three groups, two also attended the evolution unit, lectured by the fourth teacher during the second semester. Therefore, students’ data involves a 1-year cohort of eighty students that have contact with all four teachers, at least for 1 month.

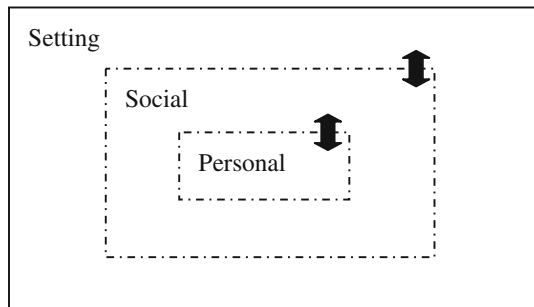
Two researchers completed an observation grid of each lecture session, paying particular attention to teachers’ interactions with students. All interviews were audio-taped, transcribed and coded for analysis, and took up issues flagged by interviewees in relation to the semester’s teaching. For the purposes of this paper we report interviews with eight students. Data were also collected from the university’s web-based e-learning systems, used by both teachers and students. Each element of this qualitative data was validated using respondent validity in each case.

Conceptualising contextual zones for questioning

Our starting point is that the asking of questions is context dependent. In this work we are interested in conceptualising ‘contexts for questioning’, in moving beyond teaching as the prime criteria for building an environment where students’ classroom questioning is the norm. For us, a context is the set of entities that influence action in a particular setting, situation or on a specific occasion (Brezillon 2003, 2005), in particular the ‘physical, emotional, and intellectual environment that surrounds an experience and gives it meaning’ (Caudron 2000, p. 55). In this sense we delineate a context as being entailed by three dimensions, namely: (1) personal, (2) social and (3) setting. Our sense of those dimensions is that they are interdependent (Fig. 1).

This view argues that the scope of contextual features (dimensions) is defined dynamically, context is relevant to particular settings, instances of action and particular parties to that action. That is, context is embedded in activity and arises from it. Taking these elements once at a time:

Fig. 1 Dimensions of ‘questioning contexts’



Personal/Individual: individual dispositions, conceptions, skills, competencies, participants’ mental and physical states, moods, engagement, expertise. Focusing on the teacher: a vast body of research argues that teachers can be seen to have discernible teaching and learning conceptions, which influence their teaching intentions and therefore their ‘modes’/ ‘styles’ of teaching (Barak and Shakman 2008; Barbosa et al. 2004; Kane et al. 2002; Postareff et al. 2008). From Trigwell and co-workers’ studies, we have attributed to their teaching approaches the propensity to encourage student questioning (Pedrosa-de-Jesus and Silva Lopes 2008). In addition, (Watts and Pedrosa-de-Jesus 2005) we show that some students have a greater disposition to questioning than others, and that this can also depend on the means by which the teachers allow them to ask questions (orally in class, in writing during sessions, by email or through web-based ‘chat’ forums). This leads us to the second level/dimension/component of the ‘context’ for questioning:

Social: this involves the learning community, the relationships between teacher and students and also between students, the dynamic of the classroom tasks (‘joint-actions’—Clark 1996), how the teacher implements a particular strategy and what the participants actually do. This social dimension suggests how interactions between students can be encouraged and maximised when the teacher uses discussion clusters, small-group work or organizes project teams.

Setting: the broad location, the physical environment, the surroundings, the time, systems, access and availability of information, the ambiance; the institutional politic/control/authority. Clearly, a raked lecture theatre has very different environmental dynamics to a small seminar room ‘in the round’; a science lab to an art studio; a formal conference setting to an informal classroom (Watts and Pedrosa-de-Jesus 2006). While, technically, each setting allows for questions from the ‘floor’ and answers from the ‘lectern’, some are clearly more inhibiting than others. In this work, we observed lectures in a mix of university science environments/rooms: lecture theatres and smaller, traditional rooms with ‘desks in rows’. *Setting* also relates to the ‘pace, space and place’ (Coole and Watts 2009) of teaching, learning and question-asking. Question-asking changed quite noticeably, for example, when students had the opportunity to ask questions in an online forum or by email. In the latter case, they could ask when the time was ripe for them, in the middle of an assignment, in the middle of the library and/or in the middle of the night (Watts and Pedrosa-de-Jesus 2005).

Two polarised contextual zones: high formality (Zone 1) and low conformity (Zone 2)

To polarise the discussion so far, to sharpen contrasts, we have used the expressions Zone 1 (a high-formality context) and Zone 2 (a low-conformity context), as described below. The two zones indicate the ‘authoritative-pedagogic distance between teacher and taught’

related, in this instance, to the teachers' use of a range of approaches to teaching, and their ease or unease with students' interactions and contributions through questioning. We introduce some of the teacher and student interview data and our intention is to use this as illustrative of the two contextual questioning zones, rather than categorise and classify student or teacher talk.

Zone 1: From our perspective, Zone 1 tends to be dominated by a traditional ethos: formal lectures, prescribed laboratory sessions, structured tutorials, and teacher-dominated questioning. It is through direct and indirect questioning that the authoritative expert manages the zone. By definition, this high-formality zone has an unequal relationship at its core because it is the teachers, as the authoritative experts, who hold access to knowledge. Learners can ask questions but, as much research has pointed out, when these do occur, learners' questions tend to be infrequent, fairly routine and information-seeking (Walsh and Sattes 2005). Teachers direct the level at which they accept questions, offer their knowledge and adhere to outcomes and achievement, to the levels and standards against which they are operating.

Zone 2: This is a low conformity context, related to more devolved 'pedagogic authority'. It is largely learner-focussed, de-emphasising any 'epistemological distance' between experts and novices in relation to their knowledge and abilities: there is a greater sense of students as intellectual colleagues. This zone can be associated with tutorial rooms, laboratories and to diverse teaching strategies such as small group work, problem-based learning and use of on-line learning systems. Students tend to operate in groups or 'learning sets' and work as near-contemporaries. Groups are usually established at the outset by the teacher or through informal means, with more-or-less equal power between members, the learners being inter-dependent. This means that authority is either rotated on some basis, or shared between group members. Teachers have collectivist or constructivist societal views of the distance between the cultural orthodoxy of particular knowledge.

A Zone 2 context is where learners are in a conducive social context in which demonstrably original and creative activities are rewarded with low fear of failure. It fosters original and unexpected thinking, questions that may otherwise be 'disruptive' of routine, class control, orderliness, organisation, curriculum orthodoxy. Zone 2 can be described in constructivist terms as 'communal constructivism' (Barbosa et al. 2004; Holmes and Gardner 2006). In the main, it is where the outcomes of learning are negotiated, shared and distributed, both teachers and taught prompt, provide and role model 'creative questioning'. Table 2 highlights the differences between Zone 1 and Zone 2.

Applying the model to 'real' data on teaching and learning

In this next section we illustrate each zone through interpretation and reflection upon real-life experience. We use interview data that explores both teachers' and students' experiences and perceptions of the lectures across one academic year in this discussion. First, though, some caveats:

- (1) Our aim in polarising these two conceptual zones has been one of 'polemic clarity', particularly in terms of the 'personal/individual' dimension. Trigwell, Prosser and Taylor's (1999) original phenomenographic studies, from which the ITTF and CCSF approaches were constituted, held that their five approaches formed an inclusive hierarchy, and that there is questioning in the ITTF approach as well as transmission elements in the CCSF approach. To this extent, an ITTF approach is not entirely in

Table 2 Two ‘questioning zones’

Dimensions of context	Zone 1—a context of high formality Description	Zone 2—a context of low formality Description
Individual/ personal	Socially compliant students who are inhibited in their question-asking, with few opportunities to ask informative, specialist or speculative questions in the quiescent atmosphere of a formal lecture system; teachers orientated towards ‘Information transmission, teacher-focused’ (ITTF) approaches to teaching (Trigwell et al. 2005; Trigwell and Prosser 2009)	Students reveal a high disposition to raise questions, encouraged and uninhibited by peers, teachers or circumstances; teachers orientated towards ‘conceptual change student-focused’ (CCSF) approaches to teaching (Trigwell et al. 2005; Trigwell and Prosser 2009)
Social	Formal, authoritative, exam-orientated contexts, ‘teaching to the tests’, tangible power-relationships; note-taking, assignments, laboratory classes, formalised formulaic teaching and learning tasks	Teachers create conducive social contexts in which original and creative activities are rewarded without fear of failure; fosters original and unexpected thinking, with more-or-less equity between members, enables questions; teachers and taught provide and role-model ‘creative questioning’; tasks include mini-projects, supplementary tutorials, on-line discussions, own-time learning, field work
Setting	University teaching laboratories, science lecture theatres, conferences, seminar room; week days during a university semester in Portugal (and many places elsewhere)	Tutorials, small-group work, ‘learning sets’, enquiry-based learning, mini-projects, classroom presentations, field-work, study-centres, on-line discussion forums; own-time, off-site research, on-line opportunities, self-directed, self-paced

‘opposition’ to a CCSF approach: naturally CCSF teaching will also involve transmission some of the time, but less than in ITTF, and vice versa for questioning students’ understanding (Pedrosa-de-Jesus and Silva Lopes 2011). That said, Coffey and Gibbs (2002), also using the ATI, have reported that teachers who adopted a student-focused approach used a wider repertoire of teaching methods than teachers who adopted a teacher-focused approach.

- (2) It can be the case, too, that some students are antagonistic towards more student-centred approaches (not least because of the complexities of difficult, domineering and demanding students, not seeing the relevance of some questions asked, and so on) and prefer a transmission approach. Nevertheless, Hativa and Birenbaum (2000) found students in their studies that clearly approved of a wider repertoire of teaching methods, overwhelmingly favouring student-centred (CCSF) approaches.

Microbiology contexts

As previously stated, Microbiology lectures were structured in modular form. Each of the three teachers (teacher 1, 2 and 3) was responsible for lecturing a 1-month module to the three classes. Each lecture occurred once a week and had a mean duration of 2 h.

All three teachers lectured in the same type of room, namely amphitheatres (raked lecture theatres), which can be associated to a ‘Zone 1’ setting. Despite this, non-participant lecture observation revealed that the dynamics of the lessons, in particular teacher

and students' oral interactions and student–student interactions, were quite different between lectures between the different teachers. Two of the teachers (teacher 1 and 2) had high percentages of self-answers to their own questions while, with teacher 3, self-answers were completely non-existent. Teacher 3 dealt more easily with students' interventions (questions and answers) managing to engage with the students who expressed ideas and to stimulate further reasoning. The reactions of teachers 1 and 2 to students' answers were frequently only focused on the scientific correctness of the answer. After short feedback, both teachers tended to move on, with their PowerPoint explanations.

These different 'interactional' behaviours (social dimension) seem to be rooted in different teaching and learning conceptions, and therefore intentions, identified by the ATI-R results. Teachers 1 and 2 were identified as having an ITTF approach, while teacher 3 was identified as having a CCSF approach. While teacher 3 conceptualised questions as an instrument for 'joint' understanding, teachers 1 and 2 seemed to quickly return the focus to the teacher:

Normally I provide some form of answer. When I know it, I answer. When I don't know... well I give the bits I do know from within the whole question. For the more specific parts of the question, I would say [to the student] that I have to do some research first... that I will try to know and that I will give the answer next time. Or I suggest that they talk to me at the end of the class. But probably, if the question is related to the content of the lecture, I am prepared to give an answer. (Teacher 1, talking about her reaction to students' questions)

This is the essence of the personal (and social) dimensions of Zone 1, it is the teacher who decides whether and how to provide social support and guidance, how much and to what ends, what support and guidance is needed for the learner to gain in competence. Teachers make the decisions about the level of the learner and the standards of learning to be reached, what the learner needs, what questioning is possible, what actions are required and the timescales involved. Such high-formality influences students' behaviour during lectures. Overwhelmingly, the interviewed students saw this mode of teaching, the tone of lectures, the authoritarian stance of the teacher, to be inhibitive of questioning, affecting their own disposition for posing questions during class:

I didn't ask any questions because I didn't want to interrupt the rhythm of teacher's talk. (Filipe, talking about lectures of teacher 2)

Teacher 3 (CCSF), also lecturing Microbiology is somewhat scathing of this 'high formality' approach. He calls it 'classical teacher reasoning', which he describes as:

Afraid of losing authority... but I think that is absurd... though I think that some people feel like this. It produces very unidirectional communication... the students ask, and the teacher simply gives a straight answer or ignores the question. That is the reasoning that prevails... it goes in one direction, showing who has the authority. But it might not be just an authority thing... maybe that [kind of] teacher just wants to end the 'incident' [the student's question] and continue with 'content transmission'.

Teacher 3 places himself at the 'opposite' point of view:

If students participate more in lecture then they would be less dependent on the teacher's voice. Actually, I think it would take less time to prepare the lecture itself. And, that way, the lectures would work more according to students' needs...

especially if the teachers are not afraid, to assume that they don't know if someone asks them a question. For example, for myself, after so many years, I know quite a lot of microbiology...but there are still many questions to which I don't have an answer. I think there are many teachers that are afraid of that... so they invest a lot of time in heavily structuring the lesson.

The disposition of teacher 3 towards enhancing students' own questioning was highly valued:

Yes, I feel really free to ask questions because the teacher is always ready to answer them... I recognise that he feels comfortable about answering our questions. And that's important for us, we students, to feel that motivation. (Ana talking about teacher 3)

The key-issue is that, despite the fact that physical conditions were not the most suitable for creating what we would call a 'question-based learning environment', the personal dimension of teacher 3 overcomes the setting of those lectures while, with teacher 1 and 2, this did not happen:

I don't think the teacher could have done it any other way... But it was really monotonous, there was too much content to be covered and no space for a question, no break, we just wanted to speed it up, get it over with! (Cátia)

Indeed, the context features of 'Zone 1' apply to the lectures of both teachers 1 and 2. The tasks involved in their lectures followed the traditional note-taking format and test-based teacher questioning, with subsequent impact on students' questioning:

During the semester they [students] don't study. Perhaps about three days before the exam they'll attend tutorials. And they come precisely because they haven't studied before. They'll attend those lectures on the eve of the test to hear the questions of their colleagues and to hear how we [teachers] answer. They want to know the doubts of their colleagues, those that have studied... They come with the hope that the teacher will reveal something about the test (Teacher 1's (ITTF) comments on student behaviour on the eve of tests).

Evolution contexts

At the second semester of the same academic year, eighty of the 180 students that attended microbiology were also observed in the context of evolution lectures. This was taught by teacher 4. His inventory answers indicated a CCFS approach. Conceptions expressed during interviews corroborate this result:

For me this discipline should be a space for the discussion of a theme that I, as a biologist, consider fundamental (...) discussing evolution with the students in order to make them understand all the concepts and mechanisms of evolution and the final result...all this biodiversity.... For me this discipline would be perfect if I could discuss all this things with my students out there on the grass. For me teaching is much more than explaining concepts and mechanisms. (...) [It is] helping students to deal with their knowledge (...) to make them use and expand that knowledge by discussing it with me and particularly discussing it with their peers.

These student-centred conceptualisations seem to influence the way the teacher sees the importance of questioning in the teaching–learning process, particularly students’ questions, and also the way he actually *uses* questions with students during lectures. The following interview statement is a self-description of this teacher’s reaction to student questions, which was also evident from several classroom observations throughout the semester:

I love it! And I have absolutely no problem in saying that I don’t know the answers. That’s the first thing... Obviously I don’t know the answer to everything [laughs]. I think it is very important that they put questions out there. I try to get their classmates to answer the question instead of me. I really make an effort to be the last one to say anything... I try to synthesize at the end of a discussion and to correct what was not quite correct. But, I think that students’ questions are very important. And I get really excited when that happens... when they interrupt the lecture and ask a question. I think that is extremely useful... I can’t conceive of teaching in any other way.

Being driven by a strong student-centred conception, this teacher felt ‘uncomfortable’ with the traditional lectures settings, typically at the Zone 1 pole:

- (1) Traditional classroom where students are aligned in ‘squeezed’ rows making it impossible to move and interact with students. The only free space was at front to the left and right of the classroom’s white-board;
- (2) Reduced student contact with the discipline—only a 2 h lecture per week.

Taking this into account, teacher 4 expressed the desire to complement his lectures with an Online Discussion Forum (ODF) in order to enhance students’ personal development and social co-construction of knowledge. He was hoping that such an online forum would make students think about evolution several times during the week. Previous teaching experience showed him that, without a complementary strategy, “(...) students only ‘switch on’ when he or she enters the classroom, and then ‘switches off’ once more when he or she leaves the class, and the discipline probably ‘dies’ at this point in the students’ mind.”

Therefore, and with the collaboration of two science (biology) education researchers, a ‘Question Forum’ at the university’s web site was developed. Students were challenged by an initially controversial statement written by the teacher into the Question Forum, and were then asked to formulate questions and develop arguments that supported their opinions on the topics being discussed. Teacher 4 only contributed to the discussion when he felt it was appropriate to prompt discussion or give feedback. As an example, a truncated version of students’ and teacher written interactions in the forum is as follows:

Maria:

This discussion about human evolution is causing a lot of controversy not only in this forum but also in my own thinking. Sometimes, I just start agreeing with some of the opinions I read, but suddenly these ideas seem so controversial that I can’t stop questioning myself. I have already referred to this, but I have to reinforce it again: Is it plausible to talk about evolutionary mechanisms in humans?! (...) Shouldn’t we question ourselves about the evolution of human species when all terms created/used were idealised for other species?

Teacher:

I’m writing this comment here because I consider that Maria has opened up a ‘window’ of discussion that nobody has taken up. To those that consider that

comments are always around the same topic, here we have a good opportunity to 'deviate'. (Teacher 4, after several other students' interventions)

Nuno:

In relation to the question you have asked, Maria (...) I think we have already 'overcome natural selection' and that sexual selection is not a term that can be applied to us, we have to adapt terms; 'cultural evolution' can be fully applied to human beings as well as the concept of 'meme' referred in previous comments. (...)

Maria (after several student posts):

I have been reading some comments to my last post, and I think that - eventually - my idea was transmitted in a wrong way. I'm only arguing that the disadvantages, by fact of being rational, sometimes outweigh the advantages, and that makes me reflect a lot about it. However, I'm really trying to reinforce my disagreement with the terms 'Evolution' and 'Sexual Selection' when applied directly to our own species.

This example illustrates the nature of the discussion in the forum and the role played by the teacher. He does not give direct answers or direct opinions, instead he prompts discussion, inviting other students to participate and allowing the discussion to be student focused. This way, the forum provided students with opportunities to express their critique about some topics, to question and to argument about different points of view.

Indeed the ODF helped to overcome some of the deficiencies of a zone 1 type of setting, promoting student-centred teaching. This improvement was not just recognized by the teacher, but also by the students:

In my opinion, the online forum is a very useful strategy in many aspects. First, as a teacher, it is a way to stay in contact with the students beyond the classroom. We get closer to the students. At the end, our discussion had many jokes to 'lighten' up the environment. I think that this kind of situation, between teachers and students, is very rare. In my opinion, this motivates students... On the other hand, the online discussion creates a 'chain' among them. They think "Ok. He answered... I will answer too." So, the majority of the students are connected through this online discussion and this is a great motivator. (Teacher 4)

It's very important, especially when we are studying at home. It's a means by which we can have the teacher available at almost any time. Also, before the tests, I usually like to see the questions from my colleagues and the teacher's answers because sometimes those will also be the answers to some of my own questions. (Patricia)

At least, while we are studying, we have this facility; otherwise we would have to keep contacting the teacher... Also, I think it is useful for those persons who are shy and for those who haven't the capacity and time for formulating questions during classes. (Cátia)

Of course, the ODF strategy was only effective when the teacher was actually disposed to enhancing students' questioning, with very positive effects. The following two students had been part of sessions that were openly question-based, where the strategy to involve students individually in the practice of enquiry had been developed across the academic year. The teacher's disposition towards enhancing students' own questioning was highly valued:

We have ended up developing a real willingness to ask questions, because the teacher has made us feel free and comfortable in doing so... The fact that the teacher

stimulates our questions has even helped us in other disciplines and with other teachers. (Filipe talking about teacher 4)

At this point it is important to emphasise that, in our conceptualisations, the social and personal dimensions of ‘contexts for questioning’ are nearly inclusive. Therefore, if a teacher does not have student-centred conceptualizations (personal dimension) he or she will have difficulties in interacting and engaging in a sustained way with students (social dimension).

Finally, as well as being personally more rewarding and engaging, the dynamic of working in a low-hierarchical relationship between teachers and students spilled over into forms of assessment (Pedrosa-de-Jesus and Moreira 2009). Some students stressed the importance of being assessed through online discussion forums, as a means of developing their questioning skills:

I felt an improvement throughout the year ... Practice helped us a lot, we have been training in solving those situations [problem based cases]... I think that if we continue with this method we will be able to attain a higher level in formulating questions and answering them so that we really understand things. (Ana)

I think assessment has influenced us... We have had to pose at least two questions [as part of an online discussion forum] but I ended up generating more... The first questions I asked, I felt obliged to do so. But, actually, then other questions came out spontaneously, because we start to interact, and then it became natural! (Cátia)

Final considerations

This paper addresses issues of teaching and learning in undergraduate sciences, around two broad contexts for the production and reception of students’ questioning. Our two contexts of enquiry, Zones 1 (high formality) and 2 (low conformity), are distinguished in terms of personal dispositions, social relationships and physical settings. We have used this model to discuss data related to two disciplines of undergraduate biology at a Portuguese university, in order to reflect about the ways in which questions are managed and particularly how students’ questions can be fostered in promoting active learning.

Clearly, different kinds of teaching can generate different questions. In Zone 1 traditional lectures are centred on the teacher and only few students have the inclination, skill and confidence to raise questions from the audience. The teacher dictates the forms and ‘quanta’ of knowledge transfer, the structure and the rhythm of the class, and this shapes teacher-student as well as student–student relationships. In Zone 2, sessions are geared to being student-centred with more opportunities for fostering and welcoming questions through problem-based learning, mini-projects and interactive online systems, alongside more traditional lecture formats. This context to teaching and learning is communally constructive (Watts 2003; Teixeira-Dias et al. 2005)—teachers and students are not simply engaged in developing their own information but are actively involved in creating knowledge that will benefit other students and teachers. Such ‘zones of low conformity’ are premised on the basis of broad, well-orchestrated, ‘pedagogic equity’ (Pedrosa-de-Jesus and Silva Lopes 2008). That is, together the members of the group construct new understandings. Rogoff et al. (1993, p.6) describe this as ‘*a process and system of involvement of individuals with others as they communicate and engage in shared activities*’. It moves towards a focus on transformation of learning and has, as Jordan (2004, p.42) says:

No prescribed content outcomes – the focus is on developing shared meanings/inter-subjectivity and each participant contributing to the on-going learning experiences from their own expertise and points of view.

Zone 2 is, in our constructivist terms, where learners have ‘enabled curiosity’ and a contextual framework within which to ask and explore questions, and where teachers’ reactions to questions are—at the very least—constructive and welcoming. It is learner-centred, enquiry-based learning, where the learner becomes an independent questioner—with the associated power. Questions provoke thought and reflection; strong questioning skills fuel and steer the inventive process required to understand and develop something new. They are directed towards being productive of knowledge (Holmes and Gardner 2006; Barbosa et al. 2004).

Given both the broad context for change within the ‘Bologna process’ in European universities, and our own stated preferences, it is no surprise that we are advocates of Zone 2 questioning context. However we realize that intention and implementation are not the same thing. We argue that a driving aims of university institutions has to be that of leading students towards the development of the abilities, confidence and opportunities required to ask questions. We recognise, too, that the implementation of a Zone 2 questioning context (where all dimensions are of a zone 2 type) is not arrived at easily. It entails vision and determined hard work to enhance the shift to a Zone 2 questioning context. By way of suggestion, we propose:

(1) *at ‘personal’ and ‘social’ level*: student-centred teaching and learning conceptions can be promoted by initiatives that integrate collaboration between ITTF teachers and CCSF teachers. Sharing ideas and experiences between different ‘types’ of lecturers could be one way to make the ITTF teachers more sensitive to the benefits of ‘true questioning’ through the ‘perspective’ of their CCSF colleagues. Peer-lecture observations could be one starting point for broader reflections.

(2) *at ‘social’ and ‘setting’ level*: even CCSF teachers might have difficulties in implementing all student-centred strategies (Andrews et al. 2011), particularly when elements of the settings are of type 1. Therefore, collaboration with science education researchers in designing student-centred strategies might be useful. Information technologies also can be used to promote personal development. Nevertheless, ICT is only an instrument that might be useful in promoting student-centred approaches. The key-issue still lies on pedagogy and not technology (Mazur 2009). Of course, even well designed strategies might fail when wrongly implemented (Andrews et al. 2011). Assistance from science education researchers at this level is also important in order to minimize the risk of teacher frustration and therefore the promotion of negative conceptions about teaching in a ‘student centred way’ (Andrews et al. 2011).

Naturally ITTF lectures are also welcomed to integrate research projects that involve university teachers and education researchers. We argue elsewhere (Pedrosa-de-Jesus and Silva Lopes 2011) that the shift towards a student approach does not have to start with a change of teachers’ conceptions. We believe that the changes of some teaching practices (even when the teacher makes these changes in a reluctant mode at the beginning) and the teachers’ realisation of the impact of those changes on students’ learning, might be a powerful instrument towards the beginning of a (time consuming) process of changing the teachers’ conception (Pedrosa-de-Jesus and Silva Lopes 2011, p. 240).

Despite the fact that we argue towards “low formality” questioning contexts we accept that there will be cases where teaching-by-transmission will support the learning of some

students more than teaching associated to CCSF approaches. Interviewed students, though, gave voice to a clear preference. They were overwhelmingly appreciative of a Zone 2 context, where their learning experiences were seen to be engaging and meaningful, their relationships with lecturers superior, their experiences of asking questions highly favourable.

We began this article by describing context as relational so that, arguably, teachers will adopt their approach to teaching in relation to their perceptions of the physical setting in which they work, the social role they are playing, the content of their programmes, their understanding of the students they are teaching. This, in turn, may lead them to adopt a transmission-of-information approach over low formality approach. Where this is the case, we applaud the rational decision, where Zone 1 elements, the setting or student characteristics, are deliberate factors in the approach adopted.

Despite some advances, there is much work to be done to change teaching and learning. We believe that the two questioning zone model presented and discussed here could be helpful for understanding the complex dynamics implied in this effort.

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