Witness as Participation: the Lecture Theatre as Site for Mathematical Awe and Wonder

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> It makes it all worth learning if the lecturer sounds as if he's enjoying it and he likes it, you know. (female undergraduate, second semester, first year)

In Britain, like many other countries, there is crisis in mathematics education: there are not enough mathematics teachers at the school level, not enough mathematics graduates for industry and commerce and the proportion of undergraduate mathematics majors is declining in an era of tertiary expansion. So, as mathematics educators, how do we nurture those who are attracted to mathematics? To answer this, it would help if we understood what helps students who choose to study mathematics as undergraduates to succeed - both attitudinally and academically.

Seeking this understanding motivated a team to research the attitudes and academic progress of a cohort of undergraduate mathematicians. [1] First-year interview transcripts from the project gave us example after example of students' perceptive accounts of why mathematics lectures matter. My response to their insights and communication of feelings was to aim to explain why lectures matter to them: the reasons, I believe, are related to theatrical experience and cultural belonging. So, this article puts forward a case for mathematics lectures based on the interpretative perspectives of theatre studies and a social theory of learning.

I aim to explain why, despite their well-known variable quality, mathematics lectures have a special role in stimulating the imagination and why attending lectures has a significant role in inducting students into their university's mathematical community. There is a 'spiritual' purpose in gathering the mass of students for teaching: theatrical-style witnessing of mathematics in lectures can constitute a form of participation. Furthermore, this form of participation can contribute to students' success in their undergraduate mathematics education because this witness-participation can help develop students' identities as mathematicians and can inspire mathematical imagination. And, as university lecturer John Shaw (2001) remarks:

> students still seem to attend lectures in large numbers. What is it that attracts them? (p. 27)

The following pair of quotations from interview transcripts [2] have been chosen to communicate facets of students' positive views of lectures:

Susan: It's like, I mean you find in our module G lectures, it's really quiet, isn't it. Have you noticed? It's really, really quiet, 'cos he's a brilliant lecturer. And you sit there and it's like 'I understand all you're saying, you're really interesting, you know, and this is really good'. But with our module C ones no one understands, so we sit there and talk about him going 'Oh look he's doing that, do you understand this, no'. [...] But in module G, he, he - I don't know, he obviously loves the subject - you know he's obviously like enjoying himself up there, isn't he. [ ] And it makes you want to learn it. It makes you enjoy it and, I don't know, he's just made me interested in the subject.

Oliver: I love it when [ ] you don't know it to begin with and he starts and you just watch and then it begins to fall into place and you can just see the next step and even before he's got it on the board you can see, yeah, what is going to happen. That's the beauty of maths and that's what I just love about it. I love, yeah, when you work things out and you can see what you've done and it's there to see.

These quotations draw attention to the idea that something inspiring and marvellous can happen in a lecture. The experience of being inspired by a mathematics lecture does not necessarily correlate with effective learning, in the cognitive 'learning objectives' sense of being able to respond correctly to test items. However, being put on a 'mathematical high' can contribute to wanting to know mathematics, as these students do, and this is indicative of the spiritual purpose that witnessing a lecture can engender. Hence, 'awe and wonder' can be experienced in the lecture theatre.

It is a commonplace (which our observational evidence supports, despite the choice quotations above) that undergraduates are quite critical of their lectures: they are often cross that they don't understand or they complain about the 'delivery' (Macrae, 2002). There are moves to avoid the big lecture by planning for undergraduates learning in small groups or with computer-aided learning (Alcock and Simpson, 1999; Dahl, 1995). While recognising that there might be sound reasons which could lead (or have led) to getting rid of lectures in undergraduate mathematics programmes, the 'dialectic tension' for the reader to hold in mind is: if there were no mathematics lectures, what would be lost?

The undergraduate mathematics education context

The recent ICMI study (Holton, 2001) on undergraduate mathematics teaching opens with a plea that university mathematics professors (or 'lecturers' in U.K. parlance)

should be stimulating teachers. Alsina (2001) calls on university teachers to see their students as having hearts as well as brains and "to transmit our passion for mathematics and this is something that all students may remember" (p. 11). Central to Alsina's rally is a message consonant with this article: students will perhaps be moved - spiritually as well as cognitively - by the charged environment an impassioned speaker can create

In mathematics education research that attends to mathematics undergraduates, there is a body of research studies which examines the cognitive development of students and strategies for teaching which enhances this development: Tall (1991) provides an initial mapping of this territory. More recently, the affective dimension is being woven into this analysis, as suggested, for example, by Jaworski's (2001) conception of "*harmony* between sensitivity and challenge" (p. 196; *italics in original*)

This article contributes to the on-going humanising of undergraduate mathematics education as advocated, for example, by Thomas (2001, p 35), by examining an aspect of the key student experience of attending lectures. This theme of 'humanisation' is also central to Shaw's (2001) query as to why undergraduates, in all subjects, do - despite problems - keep going to lectures He writes:

> If students are going to use the internet, we have to investigate what makes us still relevant and necessary for their learning The answer is not meticulously planned lectures that centre on delivering information. The more content that can be delivered by technology, the more we have to emphasise our role as the humanity in the machine - motivating, enthusing, leading by example. (p. 27)

Spiritual matters in mathematics education [3]

The question of what is 'spiritual' defies strict definition, but the term can be used in a broad sense to connote that which is uplifting, inspirational, delightful and which provokes some desire to give (which, in this context, includes giving time to study) The value of this wide-ranging notion is recognised by curriculum designers: in the National Curriculum for mathematics (DfEE, 1999), which is the state curriculum for maintained schools in England, there is a section on "promoting pupils' spiritual, moral, social and cultural development through mathematics" (p 8) (Each National Curriculum subject has such a section) It is stated in this National Curriculum document that mathematics potentially contributes to spiritual development, for example, by "helping pupils obtain an insight into the infinite" (p. 8). In this present article, the role of a teacher in helping students obtain such insights into topics involving 'infinity' and other abstract concepts is recognised One function of a teacher in this regard is to inspire wonder within the group of students This may not be an everyday occurrence, but it can and does happen.

A positive purpose of a lecture, then, as will be discussed here, is that a good lecture acts a site for 'awe and wonder'. (This is a phrase which is used in describing, with a little irony perhaps, pupils' spiritual development within the National Curriculum and Religious Education in England, e.g. http://pathways uwe.ac.uk/spiritual/moral/default asp last accessed 2nd January 2003.) The idea is that some 'spiritual' experience can occur in a good mathematics lecture and this experience is motivating for students and contributes to their enculturation within a mathematics community

From literature on lectures

In 1972, the British university lecturer Donald Bligh wrote a provocatively titled book 'What's the use of lectures?', in which useful techniques for new lecturers are presented, along with a glossary of published work on lecture-based learning and a critically orientated discussion as to whether the undergraduate university lecture is actually effective. Bligh points out features of good teaching which do not generally happen in lectures For example, he reminds us that "learning to think is not an absorption process" (p 53); that the traditional lecture is a "one-way verbal communication", yet "feedback [is important] for learning" (p. 124); that social interaction is a strong motivator for people "Yet the lecture method notoriously neglects it" (p 80); that enthusiasm aides learning (p. 80).

On this last point, concerning the "inspirational function of lectures", Bligh makes some comments pertinent to this article: firstly, that while there are likely to be some inspiring lectures, these are few in the overall count (p. 39); secondly, he is sceptical that lectures could generate a "good group spirit" which he acknowledges is an important variable in affecting students' attitudes (p 47); thirdly, that "some acting ability may be advantageous to a lecturer who wishes to enthuse his audience" (p 80).

It is to the nature of audience and the capacity for individuals in audiences to be changed as a result of theatrical experience in front of an audience that I now turn, because learning involves change.

Theatre

> In ancient times theatre played a crucial, spiritual purpose within the community [. . which gathered] to witness and participate in the stories that explained and gave meaning to their existence. (May, 1990, p. 8)

What is 'theatre'? In general terms, 'theatre' is witnessed, purposeful spectacle. The relevance of theatre to undergraduate mathematics education [4] is the focus of this section. And 'theatre' is relevant as the lecture theatre is a site for an authoritative delivery important to the audience of potential mathematicians. The lecturer is both communicator and guardian of knowledge and this dual role is analogous to the centre-stage figure in May's characterisation of ancient theatre: "The actor/storyteller and the shaman/priest were one and the same" (p. 8).

The lecture offers potential for awe and wonder, just as the theatre does The study of theatre is relevant to mathematics education, if only because in universities across the globe young adults gather to listen, take notes and watch the story needed for the next stage in their life unfold: the mysteries of the calculus, the structure of algebraic objects, the solutions of differential equations. They are initiated (at least in part) by their experience in the lecture theatre

In the rest of this section, I consider those aspects of the theatre which illuminate why there is a positive purpose to the mathematics lecture. This is not to say that I am advocating a system in which all teaching is done through lectures. Indeed, to preview the conclusion and develop Shaw's earlier mentioned exhortation to "humanise", the function of lectures should, perhaps, be more to draw students together through the experience of witnessing mathematical processes and drawing attention to mathematical forms, rather than expecting the students' ritualistic taking of notes to be a firm foundation for their developing knowledge.

Performance

> performance arouses the most fundamental of all dramatic emotions: wonder. (Mudford, 2000, p. 3)

Student experience in lectures is conducted by the lecturer and constrained by the mathematical material of the curriculum. There is an onus on the lecturer to 'give a performance'; it is not sufficient merely to 'deliver the material'. Students (in our project) remarked that the personality of the teacher/lecturer was important, as was engaging with the student audience.

> Leah: Yeah, they're maths lecturers, they're at uni so they must be good, but maybe they haven't the personality to be teachers, maybe they just want to do maths and that, 'cos sometimes you feel they aren't interested in us, in us students, they don't know us, they aren't interested in us and cos we're first years the stuff they're teaching us is like so easy for them they find it boring, and they'd like rather be doing more difficult more harder maths and well it's just something they have to do and that, so. But some are like really lively and so that helps a lot 'cos you think, this is good, he likes it and so you like it 'cos it seems worth learning

The perspective of theatre studies offers descriptors for performance and more delicate explanations for a performance's success or failure. For example, great performances involve risk, a relationship between the performer(s) and audience, and a continuation in the imagination of the members of the audience long after the curtain has fallen (Mudford, 2000, pp. 1–44). These are the same qualities which students are clamouring for in their lectures; students readily praise lecturers who can perform thus.

James Nicola (2002), in his recent manual for actors, says:

> Live acting, then, is not just about what you feel, it's about what you get the audience to feel [...] The secret to achieving all this lies not simply in performing in front of, but in participating with; not in what one says or does, but in what one gives; not in showing, but in sharing; not in what goes on inside oneself, but in what transpires *between* actors and audience. (p. xii; *emphasis in original*)

Adapting this quotation to the mathematics lecture context illuminates the centrality of the theatrical analogy for university teaching:

> Lecturing, then, is not just about what you understand, it is about what you get the students to understand. [...] the secret to achieving this lies not simply in lecturing in front of, but in participating with; not in what one says or does, but in what one gives; not in showing, but in sharing; not in what goes on inside oneself, but what transpires *between* lecturer and students.

Nicola goes on to try to capture the energy in the effort of challenging communication by this concept of 'between' and invokes a spiritual aspect through his choice of example:

> Michelangelo was aware of this power of between; magnificent as all the Sistine Chapel's paintings are, the focus of the room is the very centre of the ceiling, the point between God's and Adam's fingers, where he painted nothing. (p. xii)

Multi-modal experience

Another attribute of lectures could be called 'the multi-modal approach' and this relates to the theatrical aspect of lecturing. Clearly, in a performance several forms of communication are being offered, which Janusz recognises as being helpful to him:

> Janusz: . if you're there, you know that it's information you can actually take in, and it's a different way of taking in the information actually hearing it rather than reading it so.
>
> Interviewer: That's interesting. Can you say more?
>
> Janusz: Sometimes you read it and you think, well I think I understand that but then you hear it and it might even be the same words as are in the notes but somehow you hear it differently to what you read and sometimes it just clicks that way, there's something different in hearing it and reading it. I'm not sure what it is, but that has happened a few times and that's good, I like when that happens 'cos it usually means that it sticks in my head.

Alsina (2001), in calling to for the communication of passion and enthusiasm for mathematics, rejects the notion of a "mathematical play", while advocating aspects of multi-media communication with students. This draws attention to the difference between amateur dramatics – where props indeed support a 'play' – and an uplifting and inspiring performance which includes props for communicating insight. For example, while a lecturer might use a graph plotter for many graphs in a lecture and the students cannot see the wood (purpose) for the trees (data), another lecturer might ask the students to imagine the set of curves given variation of a parameter before using a graph plotter to display the solution set.

However, an 'awe-inspiring' performance does not occur whenever a set of appropriate competences is satisfied. It

takes more than technique to lift the spirit and direct the intellectual energies of the (typically) 18–22-year-olds who are aiming for a mathematics degree. For example, in an early second-year lecture, the lecturer 'Dr. Y' employs many of the techniques that the students have been saying are important and that Bligh (1972) advocated: the notes are exemplary, he faces them when he speaks to them, his writing is clear, he does examples 'live' and he has a strong, audible, 'BBC' voice. He speaks about the mathematics, then writes on the board, and he turns things round trying to give the students different ways to get to grips with the new topic. This new topic is related to other mathematical ideas they will have studied: carefully, he traces application of linear maps in the differential geometric context, slowly building up the techniques that will be needed to locate singular points of mappings and, eventually, surfaces.

However, there is chat during the lecture, which he tries to control with hard stares but eventually comes out with "will you just stop it please for christsakes this is ridiculous". This man is very competent, thoroughly prepared, fluent, vigorous. He answers the only two student questions sharply: "Sir, where did you get that second basis from?", reply, "I made it up"; "What if $x = 1$?", reply, "That point is excluded from the domain of the function". You can't expect much more than what he is doing. But his disdain for the students comes through.

For example, his board writing of zero has a tail and he remarks of some matrix entries "No, they are not sixes", (that these entries were 0 was apparent from the context). And "It might not be immediately obvious to you, but one is a multiple of the other" (of vectors (1,3,-2) and (-2,-6,4)). Dr. Y gave a multi-modal presentation, but there has not been 'participation'. The audience of students has not been 'played' to by the actor/lecturer in Nicola's sense and the atmosphere is flat, uncharged, unexcited.

This example is intended to show that good 'multi-modal' lecturing techniques are not enough. A central point of this article is to distinguish between a lecturer who is a knowledge-rich 'sage on the stage' and one who is a 'leader of minds'. The 'leader of minds' draws new people to his or her world. Their lectures have a 'meta-learning' purpose in fuelling the students' desire to learn mathematics.

What is 'active participation'? Witness as participant

One of the features of a standard lecture or theatrical performance is that participation is not necessarily a function of verbal or physical interaction. A contemporary threat to lectures is the dominance of overt social interaction within the teaching paradigms currently advocated (e.g. 'interactive teaching'). As Shaw (2001) remarks:

> if active learning is the only useful part of the higher educational experience, then the large lecture, no matter how many ingenious and participative exercises are worked in, can be viewed only as a tutorial with too many students in it, i.e. a cost-cutting device." (p. 27)

Mudford (2000) sums up the theatrical notion of 'active participation' which does not involve students offering their explanations or coming to write on the board:

> In this active participation, the performance will determine not only the degree to which the audience is 'rapt' but also when the play is done what it reflects on, what it has been moved by, what it rationally assents to. A performance continues in the mind after the performance is over; and we ask ourselves what we have witnessed. (p. 8)

This notion of active participation illuminates the power and purpose of a lecture: students are kept 'rapt' by the mathematical ideas presented and are 'lifted' to reflect and review afterwards.

Nicola also analyses this type of participation. He conceptualises the audience's experience as being *worthwhile*, *unique* and *essential* (p. xii) in a 'participated-in' performance: *Worthwhile*: "The sequence of clues provides the mystery's structure. [...] You may even feel cheated in the last chapter if you find out that the inspector knew something you could not possibly have known." *Unique*: only through the play, only through "transporting live audience and actors, together". *Essential*: "for our audiences to consider the ritual essential, we must treat it as sacred [...] and leave the theatre *changed,* however slightly, for having participated in the drama" (pp. xii-xiii, *emphasis in original*).

Interpreting these three concepts for the mathematics lecture theatre gives further insight into the role of lectures in undergraduate learning. For is not a lecture only worthwhile if the mystery of a mathematical structure, concept or theorem is revealed via the clues (of the proof) in a fashion they could not extract from down-loaded information? The uniqueness of the occasion is not captured by the lecture notes alone. You have to be there. And, when it works, the students leave having been changed by the experience.

Now anyone can walk in off the street and attend a big mathematics lecture, but the people who are intended to reflect on, review and, indeed, practice and apply the content of the lecture are the mathematics undergraduates of the lecturer's university. These students attend the lecture, engage in other rituals like exercises and exams, and gradually, to greater and lesser extents, belong.

The theatre studies' discipline has offered a way to theorise 'active participation' in a lecture. But active participation in a theatre setting alone does not capture the importance of lectures in learning university mathematics. An audience at a regular theatre disperses after the performance, whereas undergraduates go through the same ritual of attending the lecture theatre several times a week for three or four years. And they go to lectures as a peer group, becoming better acquainted with their lecturers as the years go by. A 'community of practice' develops. This notion has been theorised by Etienne Wenger (1998) as part of his social theory of learning and it forms the backdrop for the second strand of my explanation of why undergraduate lectures can serve a spiritual purpose.

Identity, imagination and inspiration

> Mathematical thinking is concerned essentially with imagination and not with manufacture, and that our imagination is fed by feelings and beliefs, just as much as it is by figures and objects. (Bishop, 1988, p. 42)

Mathematics education has for some time been working on linking learning with enculturation (in Bishop's terms) and participation (in Wenger's). In particular, mathematics education recognises the role of teachers in inducting initiates into the culture, as happens at university (Bishop, 1988). Wenger's social theory of learning has developed this view further. The crux of Wenger's theory is: what you learn shapes and is shaped by what you do and by who you are. Undergraduates' learning is a function of their social environment:

> Issues of identity are an integral aspect of a social theory of learning and are thus inseparable from issues of practice, community and meaning. (Wenger, 1998, p. 145)

Informed by key notions of Wenger's theory - identity and imagination - this section continues to develop the notion of 'witness as participant' within the domain of mathematics lectures for undergraduates.

Identity and community

The practice of attending mathematics lectures belongs to mathematics students specifically and these individuals develop as a function of that participation. Their identity is moulded by being with all those other students in classes about 'linear algebra', about 'stats', about 'real analysis', etc. However, it is not just about receiving the lecture's specific content, but also about engaging in "experiments of identity" (Wenger, 1988, p. 268), experiments which are taking place concurrently. Their community is established by practices, such as attending (or skiving off) lectures, doing 'homework', participating in tutorials, sitting exams, joining the 'maths society' and just being seen around the department and being familiar with its personalities. Students "invest [them]selves" in meanings which provide the source for the "energy required for learning" (p. 266).

For example, students are aware of belonging to the undergraduate mathematics community when it comes to getting their assignment problems done:

Oliver: Maths is such a good subject for sit[ting] round, little group of six or seven of you, and then when someone's got a question there's always someone to help, d'you know what I mean?

Melanie: Even if you don't know them, if you're sort of stuck on a problem, you sort of join together.

There are also comments within the interviews which indicate that they may be at least subliminally aware that lectures bring them together, for example (from a three-student interview):

S1: Dr X he's always taking votes.

S2: He is our best lecturer.

S3: We have a break in the middle of the lecture and he puts some mathematician up that nobody knows and asks who it is, and then talks about him. [5]

In Wenger's terms, Dr X is helping students align with the mathematical community by introducing them to some cultural icons of that community; their identities are being shaped by having these people within their minds and imaginations. His doing this job in a way which increases students' pleasure also contributes to drawing them in to the university's mathematics community.

Imagination and belonging

This notion of 'belonging' (Wenger, 1998, pp. 173-183), central to a community of practice, requires potential participants to engage with the practice, to imagine working creatively with the objects of the practice and to align themselves within the constraints of the practice. The extract below from an interview with Michael captures a dual aspect of imagination - the projection of self and the creative play with mathematical 'objects' - which is central to the positive function of developing imagination with respect to mathematics.

Michael: I want to be a lecturer myself when I get older. I told you that, didn't I? So I just go off and do lecturer-like things, like researching mad ideas.

Interviewer: Is that what they do?

Michael: It's what I imagine they do. Not long ago, I was researching the idea that you could have vectors which had non-real dimensions or non-integer dimensions.

The lecturer has a role in promoting this belonging. Tony Barnard (in Barnard and Morgan, 1996) expresses a general aim of one of his undergraduate courses as helping "students in the transitions from concrete to abstract mathematical thinking" (p. 44) and a specific aim of relating results within mathematical 'culture' (p. 46). He tries to paint a bigger picture which might inspire them and he tries to draw the students into his - the mathematical - world, by appealing to the affective and the aesthetic. He points to 'mathematical jewels' which those in the mathematical community value and opens the door to these students becoming people who appreciate these theorems too.

Inspiration and motivation

The following quotation offers a student's comparison of positive and negative lecturing styles. It graphically illustrates the power of personality in communicating mathematics: it is 'just nicer to be there' when the student's gaze is towards a person rather than a piece of paper.

Philip: Well, you've got, there's this sort of teaching style, where they talk about something, then write and then talk a little bit more, while you're writing or just finishing off writing, and go at it in a couple of different angles, and not just say, this is how it is. I think it's stuff like, people who've just got a little more something about them, people who've got a little bit of humour,

> just, even if they're making bad jokes occasionally, just, that keeps you interested and looking at them rather than looking at the board and burying yourself, and you're like in your own little world, from paper to board, back to paper and everybody's like that, no contact and the lecturer's the same, from his notes, talk to himself, write it on the board, back to his paper, bit more talk to himself but so you can hear it and back to the board and he's in his own world, everybody in their own world, writing, looking, writing, it's just like, my pet hate is like looking at paper, board, this is the lecturer as well, it's just they can't enjoy it a lot more, the lecturers, I can't see how anybody can enjoy that. I find that I'm not, because I'm fed up watching the whole time, say in module C, waiting for him to finish writing. And in the other lectures you're sat there learning and it's just nicer to be there.

Undergraduate learning is frequently triggered by those unique events which contribute to an individual's agency or self-motivation, as the above quotation from Philip illustrates. However, the lecture can (though perhaps rarely does) stimulate a needing to know or a desire to be part of the mathematical enterprise. How the lecture might do this is not by conveyance of information alone (although this can work for those already hooked [6])

A student's inspiration arises from, among other factors, an unpredictable combination of perception of subject matter and identification with or esteem for the lecturer-authority: the profess-'er'. The mass witnessing of a professor's mathematical performance contributes to the shared knowledge and rituals of a community of practice. In ancient Greek theatre, "drama [..] occurred in a continuum with other institutional activities" (Blau, 1990, p. 12). Analogously, being part of the audience in an undergraduate lecture theatre is one part of a spectrum of events which constitutes belonging to the (university's local) mathematical community.

Inspiration contributes to stimulating the imagination which, in turn, develops identity. Wenger (1998) refers to imagination as the "expanding of our self [..] playing scales on a piano and envisioning a concert hall" (p. 176). The mathematical work goes hand-in-hand with the growth of self; learning is inspired by mathematical highs and mathematical personalities. Our interviews showed that undergraduate mathematics students could be entranced by the wonder of mathematics and, even though this delight dips or, for some, is rarely experienced, they invariably keep going, as a group and as individuals, seeking out positive experience.

Conclusion

> The exclamations which greet the artist on the high trapeze make audible the silent wonder with which we respond to those who have mastered an art, and give to their audiences the shock of recognition at seeing how things are, by drawing us for a time into their illuminated space. (Mudford, 2000, p. 44)

What experiences could serve as the mathematical-learning equivalent of being drawn into the illuminated space of the mathematical 'master' (to paraphrase Mudford's quotation)? Lectures. Good ones. Lectures which attend primarily to orienting the imagination of the initiates, to establishing a team spirit and challenging mathematical play. Lectures which provoke participation as mathematising is witnessed. The notion of 'participatory witness' links the 'theatrical' and the 'social' in the context of undergraduate mathematics lectures.

Here, I quote Wenger (1998) again, whose social theory of learning has been used to explain the contiguity among the notions of identity, imagination and inspiration for mathematics undergraduates:

> One cannot stress enough that these aspects [orientation, reflection, exploration] of an infrastructure of imagination are matters of identity, not just of information. [..] it is more important for the informational content of an educational experience to be identity-transforming than to be 'complete' in some abstract way. (p. 273)

What would be lost if there were no lectures? Not just loss of 'economy' in terms of 'delivery' of information! This is a poor use of lectures, even though traditional universities educating undergraduates do seem to structure their curriculum primarily in terms of information delivery via the lecture theatre. What would be lost is a singular opportunity for simultaneously inspiring and inducting, for lifting the spirit and directing desire for learning.

The view that the mathematics lecture is an out-dated teaching medium relying on an unsound 'transmission' conception of learning has been challenged here, both by students' expressions of wonder and the theoretical perception of their expressions which construes the lecture theatre as a site for participation of a special sort. Lectures have the potential to develop students' identity within a mathematical community by means of using theatrical experience to stimulate their imaginations and to inspire them to act. Shaw (2001) also contends, "that there is something unique, useful and relevant in the lecture [ ] like a jazz performance in which the musician's improvisation can thrill" (p. 27). He quotes the jazz legend John Coltrane who observed: 'it seems to me that the audience, in listening, is in an act of participation, you know'. (See also King, 2001.)

The principal suggestion for practice coming from this article is that university mathematics departments recognise the potential of lectures, not as information-delivery venues, but as a place where the 'awe and wonder' of mathematics can be experienced. For feelings can be aroused and beliefs can be developed in theatre, even in a lecture theatre. A performance can communicate images, ideas or structures which can excite the imagination. As mathematics is by nature abstract, the role of the imagination is particularly important. The stimulus that Oliver spoke about was generated by the lecturer and inspired the student.

Oliver's feeling of excitement and participation was fed by the lecturer; the anticipation of understanding something new but graspable was a theatrical 'edge-of-the-seat' experience. One reason that students continue to go to lectures together is for the possibility of jointly witnessing mathematics performed by an inspiring professor.

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Notes

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[2] Within their first interviews in their first year, students were asked about lectures if they did not themselves spontaneously offer comments; hence, all of these interviews included commentary about lectures Of these 19 first interviews, 7/19 included positive comments on lectures (6/19 included negative commentary, the remaining were neutral)

[3] There are a few recent pieces of writing on spiritual aspects of mathematics education: e g. Morris (1995), Watson (1999), Huckstep (2001) and Sinclair and Watson (2001).

[4] An anonymous reviewer of a draft of this paper pointed out that Wertsch, del Rio and Alvarez (1995) have discussed Burke's (1969) notion of 'dramatic action' in the context of mediators of action from a sociocultural perspective on education generally

[5] 'Female mathematicians' are also included!

[6] "Focussing on an institutionalised curriculum without addressing issues of identity thus runs the risk of serving only those who already have an identity of participation with respect to the material in other contexts." (Wenger, 1998, p 269) Mathematics departments in universities, which preach to the converted or school the already schooled, contribute to the on-going lack of diversity within the mathematical community.

References

Alcock, L and Simpson, A. (1999) 'The rigour prefix', in Zaslavsky, O (ed), *Proceedings of the 23rd Conference of the International Group for the Psychology of Mathematics Education*. Haifa, Israel Institute for Technology, **2**, pp. 17-24

Alsina, C (2001) 'Why the professor must be a stimulating teacher: towards a new paradigm of teaching mathematics at university level', in Holton, D (ed), *The Teaching and Learning of Mathematics at University Level: an ICMI Study*. Dordrecht, Kluwer Academic Publishers, pp 3-12.

Barnard, T and Morgan, C (1996) 'Theory and practice in undergraduate mathematics teaching: a case study'. in Puig, L and Gutiérrez, A (eds), *Proceedings of the 20th Conference of the International Group for the Psychology of Mathematics Education*. València, Spain, Dept. de Didàctica de la Matemàtica, Universitat de València, **2**, pp 43-50

Bishop, A. (1988) *Mathematical Enculturation. a Cultural Perspective on Mathematics Education* Dordrecht, Kluwer Academic Publishers.

Blau, H. (1990) *The Audience* London, The Johns Hopkins University Press.

Bligh, D (1972) *What's the Use of Lectures?* Harmondsworth, Middlesex, Penguin.

Burke, K. (1969) *A Grammar of Motives,* Berkeley, CA, University of California Press

Dahl, H. (1995) 'Teaching small groups at Agder College , No 2. *Teaching and Learning Undergraduate Mathematics Newsletter,* Leicester, Leics, The Mathematical Association. (http://www bham ac uk/ctimath/talum/ newsletter/talum2. htm#agder)

DfEE (1999) *The National Curriculum for England: Mathematics* London, Department for Education and Employment and the Qualifications and Curriculum Authority.

Holton, D. (ed) (2001) *The Teaching and Learning of Mathematics at University Level. an ICMI Study* Dordrecht, Kluwer Academic Publishers

Huckstep, P. (2001) 'Mathematics and human well-being', *Mathematics in School* **30**(2), 10-13

Jaworski, B (2001) 'University mathematics teaching – where is the challenge?', in van den Heuvel-Panhuizen, M. (ed), *Proceedings of the 25th Conference of the International Group for the Psychology of Mathematics Education,* Utrecht, The Netherlands, Freudenthal Institute, **3** pp 193-200.

King, K (2001) 'Conceptually-oriented mathematics teacher development: improvisation as a metaphor'. *For The Learning of Mathematics* **21**(3), 9-15

Macrae, S (2002) 'Not many of them are teachers , paper presented at European Research Association, Lisbon, University of Lisbon, September

May, T. (1990) 'Theatre in the wild', *Earth and Spirit.* Late Winter, 8-24

Morris, G (1995) 'Developing the spiritual in mathematics', *Mathematics Teaching* **153**, 36-37

Mudford, P. (2000) *Making Theatre: from Text to Performance* London, The Athlone Press

Nicola, J. (2002) *Playing the Audience.* New York, NY, Applause Theatre and Cinema Books

Shaw, J (2001) 'How to turn thrifty lectures into rich jazz recitals'. *Times Higher Educational Supplement,* September 21st, p 27

Sinclair, N. and Watson, A (2001) 'Wonder the rainbow and the aesthetics of rare experience'. *For the Learning of Mathematics* **21**(3) 39-42.

Tall, D (ed) (1991) *Advanced Mathematical Thinking,* Dordrecht, Kluwer.

Thomas, J. (2001) 'Policy issues', in Holton, D. (ed.), *The Teaching and Learning of Mathematics at University Level: an ICMI Study.* Dordrecht, Kluwer Academic Publishers, pp 27-36

Watson, A. (1999) 'Working on wonder and wondering: making sense of the spiritual in mathematics teaching', *Mathematics Education Review* **11**, 25-34.

Wenger, E (1998) *Communities of Practice: Learning, Meaning and Identity* Cambridge, Cambridge University Press.

Wertsch, J., del Rio, P. and Alvarez, A. (eds) (1995) *Sociocultural Studies of Mind,* Cambridge, Cambridge University Press