Formative assessment in the learning and teaching of design and technology

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Abstract
The first parts of this paper summarise recent work on the development of formative assessment methods, set out a precise definition of formative assessment, and discuss briefly the aims of Design and Technology which such methods should help to achieve. The following sections discuss in turn feedback in questioning and classroom dialogue, feedback given in writing, peer- and self-assessment and its link to development of peer-group work amongst students, and the formative use of assessment designed primarily to serve summative purposes. These sections include examples of classroom work in design and technology, drawn mainly from other authors. In a closing section I argue that any successful development of formative assessment will depend on implementation of two key strategies. One must aim for careful selection and presentation of tasks which both reflect the key aims of the subject and provide opportunities to engage students in formative dialogue. The other is to create opportunities, including allotted time, for collegial sharing between the various teachers of these students in order to secure both consistency for those students and mutual support between teachers in developments which have been found to be both challenging yet rewarding.

Key words: assessment, formative, summative, feedback, dialogue, self-assessment

1 Background history

This paper has its origin in a review of research, published in 1998 both as a full article and as a short booklet (Black and Wiliam 1998 a,b), which established that there was strong evidence from research that formative assessment can raise standards of student achievement. Their evidence was analysed in more detail by Nyquist (2003) who concluded that the learning gain was greater as the quality and scope of the formative work was enhanced. This led the group at King's College to explore the potential for practical improvement by collaborating in a two-year project with a group of forty teachers of English, mathematics and science, from six secondary comprehensive schools. Almost all of the teachers were positive about the project's effects for them, and there were significant gains in test performance for the classes involved (Wiliam et al.,2002). The findings were summarised in a second short booklet for teachers (Black et al. 2002), and reported at length in a book (Black et al.,2003).

At the same time between 1998 and 2000, researchers at the Centre for Science and Technology Education Research (CSTER) at the University of Waikato, in New Zealand, undertook similar work with thirteen year 1 to 8 teachers from five schools to explore the potential for practical improvement of formative assessment in technology classrooms, in the Learning in Technology Education (Assessment) Project (LITE). Another three-year project began in 2005 - the Interactions in Science and Technology Education (InSiTE) Project, in which ten year 1 to 8 teachers from seven schools were involved in further explorations of formative assessment in their classrooms (Moreland et al., 2007).

The outcomes of the two CSTER group projects mirrored the Kings' outcomes in that all the teachers were positive about its effects for them, and there were significant gains in technology learning outcomes for their classes.

Since then, formative assessment has become a central feature of several national and regional initiatives. The King's team has worked with teachers in all subject areas, and has found that formative assessment has *generic* features, which will apply to learning across all stages and all school subjects, and features which are *specific* – to primary teachers and to individual secondary subjects.

In this paper I first explain the meaning of formative assessment. Then a brief summary of the aims of design and technology teaching is followed by four sections describing different methods of implementing formative practices. In a final section I outline the two key features for developing a strategy to enhance formative assessment.

I draw particularly on three sources: a book chapter by Atkinson and myself (2007) and two of the Black Box booklets, Working Inside the Black Box (Black et al., 2002) and Design and Technology Inside the Black Box (Moreland et al., 2008).[1]

1 A short version of this paper was presented at the annual Design and Technology Association conference in Loughborough in July 2008.

2 The meaning and implications of formative assessment.

It is important to define formative assessment clearly, as follows:

> *Assessment for learning is any assessment for which the first priority in its design and practice is to serve the purpose of promoting students' learning. It thus differs from assessment designed primarily to serve the purposes of accountability, or of ranking, or of certifying competence.*
>
> *An assessment activity can help learning if it provides information to be used as feedback, by teachers, and by their students in assessing themselves and each other, to modify the teaching and learning activities in which they are engaged. Such assessment becomes 'formative assessment' when the evidence is actually used to adapt the teaching work to meet learning needs.*
> (Black et al., 2002)

Effective learning demands an alternation of feedback, student to teacher and from teacher to student. Thus the starting point for a classroom activity may be a question formulated by the teacher to ascertain the students' existing understanding of a topic. This implements a first principle of learning, which is to start from where the learner is, rather than to present strange new ideas to overlay the old and so cause confusion.

Then the teacher has to use this feedback to modify the teaching plan, so that the new vocabulary and structures can be introduced through challenging activities for the students which have the potential to extend their learning. In this way, teachers are implementing a second principle of learning, which is that – learning cannot be done *for* learners, it has to be done *by* them, albeit with the teacher supporting any new input.

3 The context of design and technology teaching

Whilst the generic character of formative assessment ensures that it is applicable to all school subjects, there remains a question whether it is more or less, or simply differently, applicable between different subjects. Experience of working with teachers of mathematics and of English in the same project (Black et al., 2003) showed up some clear differences. Mathematics education can be seen as the learning of a series of algorithms applied to abstract problems: such an approach leaves little space for personal interpretation, and creates little by way of either need or opportunity for discussion. Such an approach is of course presents a traversty of the nature and practical value of mathematics, but is often the one adopted by some – by no means all – of its teachers and reflects the view held by many adults. By contrast, in English there is no 'right answer' even in the writing of a technical guide, let alone in fiction or poetry. There is instead a possible range of high-quality outcomes, so judging any product, or guiding one's own progress in striving for one's own, cannot be guided by rule – one has to become a connoisseur, developing judgment through encountering and appraising a range of good models. There can be algorithmic rules of punctuation, spelling, and so on, but on their own these only generate dull, even obscure, writing. Initially formative assessment was found in the project to strike a far more familiar chord with teachers of English than with their mathematics colleagues, for developing each individual's contribution through discussion, through feedback sensitive to the personal response, and through development of self-assessment, were much closer to existing practice in English. The question then is how design and technology is located in this spectrum between algorithmic mathematics and creative English.

The central feature of technological literacy is the understanding that intellectual and practical resources are applied to intervene in the world through the development of products, systems and environments. Whilst such work must draw on a wide range of techniques and other resources, learning in design and technology (design and technology) involves generating several ideas for solving a problem or meeting a need, working often in teams, to build models of agreed design plans, and then developing or adapting these plans. Through several such iterations students should choose a final design and then build a working prototype.

The main components on which such achievements can be built are:

- identifying the knowledge that is useful to the design task in hand;
- seeking out and acquiring the knowledge required - whether through reading, or observation, or questioning;
- judging, in using the findings, the extent of the knowledge that is required: deciding how much one needs to know in order to be able apply knowledge successfully in the light of the performance requirements;
- willingness to take risks throughout, exercising creativity in introducing elements of novelty, whilst navigating between a bland solution and one that over-reaches itself.

Thus it is clear that design and technology cannot be taught by rote, and that its central need to develop creativity and experienced judgment calls for a formative approach. As teachers help students to manage each of the four components above, formative assessment will be crucial as it provides the gateway for the two-way feedback through which each teacher helps each student to learn how to take responsibility for choosing and steering his or her own journey (Barlex, 2003). This is a crucial aspect of learning, as affirmed by the emphasis on pupil autonomy in the DEMOS study of learning (DEMOS, 2005). Whilst all school subjects should be taught in such a way that pupils' autonomy is developed, D&T is particularly rich in opportunities for such development in that pupils can be required to make and take responsibility for their own decisions about their designs and subsequent products.

Studies of students' progress in the subject show that younger pupils (6 to 7 year olds) think that technology is about improving and bettering technologies and lives, whilst older students develop a broader view, believing that technology involves specific, purposeful design and making, and understanding that different technologies were designed for particular groups of people (Moreland et al., 2007). When teachers specifically include opportunities for students to have 'nature of technology' conversations, such broadening of concepts is fostered. Class and group conversations about technology can help achieve this broadening, and students might also use ways to record their personal ideas on several occasions and then compare their ideas. As Barlex, Jones & Moreland (2008) express it:

> *Formative assessment fits well with the aims of technology education, since its purpose is to help teachers filter the rich data that arise when students undertake technology tasks so that professional judgements can be made about the next steps in learning. Feedback, peer and self-assessment all have important roles to play in this process and, utilised properly, formative assessment can result in large learning gains.* (p.7)

4 Questioning and Dialogue in Classrooms

The essential two-way interaction between teachers and students can be achieved in several ways, but the basic ingredients are:

- rich questions,
- strategies to support participation by all learners,
- encouraging open discussion,

with all of these made possible through

- challenging activities that promote thinking and discussion.

Rich Questions

If questions are to serve a formative purpose in the design and technology classroom, it is necessary to focus attention on how well they serve this purpose – which factual questions usually fail to do. Collaboration between teachers to exchange ideas and experiences about good questions can be very valuable. It could be part of professional development to reconsider questioning techniques, perhaps to model question and answer exchanges to peers to help all to develop skilful exploration of ideas: such exploration often involves development from simple to complex questions. A good question should encourage imaginative and speculative responses and thereby help develop students' competence in asking meaningful questions themselves. Examples of good questions might be:

> About designing a lantern for a religious festival, the teacher could challenge the students with such questions as:
>
> *'Where will your lantern be used?'*
> *'What safety aspects do you need to consider?'*
> *'If we are to use a tea-light candle, how will you hold it safely in place inside the lantern?'*
> (Atkinson & Black, 2003, p.203)

Or in a task to create new bread products for teenagers

> *Have you thought about which other foods you might combine with your bread?*
> *Is it specific for a particular meal – say breakfast – or more versatile than that?*
> (Barlex et al., 2008)

Strategies to support participation by all learners

The aim of formative questioning is not simply to find out what students know but also what don't they know and possibly, more importantly, what they partly know Teaching is about helping youngsters realise the limitations of their existing thinking and then guiding them to upgrade their part-knowledge to a fuller understanding. It's the opposite of assessment of learning, where we try only to find out what students know.

Demanding questions require time for the learner to work out an answer, so the teacher ought to wait for some time before expecting a response. Rowe (1974) found that the wait time in primary science classes was very low, less than 1 second. In the King's College work in secondary classrooms, it was found that teachers could, with practice, increase their wait time to around 3-5 seconds and this had dramatic effects on the involvement of their students in classroom discussion in that:

- longer answers were given than previously
- more students were electing to answer
- fewer students refused to answer
- students commented on or added to the answers of other students
- more alternative explanations or examples were offered

Even when wait time is increased, some learners are reluctant to offer answers. Some teachers adopt a 'no hands up' strategy, taking the view that if sufficient wait time is given, then everyone should be expected to answer, so they select individuals to answer.

However, students often are reluctant to commit to an answer because they feel they may reveal their inadequacies. The teacher's role when formative questions are asked is to act as a facilitator and to encourage students both to try to answer and to listen carefully to the answers from their peers. One of the most difficult, and yet most important, aspects of any formative interaction is the skill of the teacher in responding to a student's answer. Responses will often be quite unexpected and may seem bizarre, or even stupid. A classic example was reported by Fisher (1995): a teacher asked a young child who had been making her own drawing of a real daffodil "What is this flower called?" The child's response was: " I think it's called Betty". It would be tempting to simply show that this is the wrong answer and to invite others in the class to come up with the right name. This would discourage the child, who had offered a thoughtful answer limited by the meaning she gave to the word "called", from participating in the future. It would also miss an opportunity – to open up a discussion which could tease out the distinction between individual and generic names.

This is an example of a general problem illustrated in ***figure 1*** (Black & Wiliam, 2009).
The figure illustrates the two-way interaction, between the teacher addressing a question or comment to the learner, and the learner responding to the teacher. But the two arrows are broken, to indicate that what is understood by the listener is not the message that the originator intended. Thus, it is very important for the teacher to listen very carefully to any response, and to take time to think about how the learner came to make such a response, for it is only in terms of this diagnosis that the teacher can decide how best to frame his or her next intervention. Thus ample 'wait time' may be needed by the teacher as well as by the students .

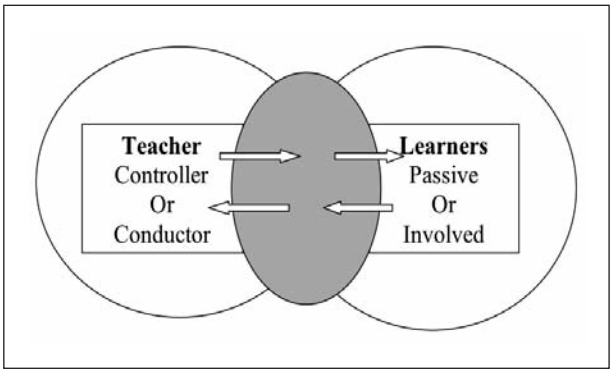

Figure 1. A simple model of formative interactions

Encouraging open discussion
Consider the following extract from a classroom discussion. The teacher has asked about a task of making a scarf suitable for an environmental group:

T: I see that you've made a start on your design. Can you just talk me through it?
P1: It needs to have animals and things on it so that they like it.
T: Mmm. I wonder if there's anything else that an environmental group might…
P2: Recycled stuff. Things that are good for the environment.
P1: But they won't want second-hand stuff.
T: Okay but they might prefer some materials to others. What do you think?
P1: Suppose. Yes, well they won't like stuff like this (rubs pencil case). Probably prefer more natural stuff. So cotton or wool or… something else natural-like.

(Barlex et al, 2008, p.20)

Here the teacher is neither giving an 'answer', nor judging responses as correct or incorrect, but provoking instead further conversation and getting others involved, at the same time giving his or her-self time to think about the ideas that are being revealed. This art of steering a conversation is a delicate skill, with the teacher's role lying between the completely passive role of letting the conversation go anywhere at random, as would happen in normal social chatting, and the opposite extreme of tough direction, which would stifle the active involvement of most students. Unfortunately, the general evidence from classroom studies is that the latter pattern, often called the I-R-E pattern (Initiation-Response-Evaluation) predominates (Alexander 2006, pps.15-17). Many teachers find it hard to break with this latter pattern, the more so because many are not even aware of how strongly they are dominating classroom discussion through the pseudo-dialogue of I-R-E. Yet unless this pattern is

abandoned, students will simply be looking for 'the right answer' rather than thinking and contributing through their own thoughts to a general discussion. A tactic that can be helpful in making this change is to avoid closed questions, and to bounce bask contributions, saying for example "What do others think of Saif's answer?", or "Can anyone improve on Jean's explanation?" Thus the role of questions can often be to catalyse extension of the thinking. More detailed advice and guidance about using discussion in classrooms is given by Dillon (1994).

Peer discussion plays an essential part in creating such an environment. If students can first discuss their responses to a question within a small group, they can explore, articulate and check ideas before they reveal their group's combined effort to the whole class. When students are uncertain, the individual reporting on behalf of a group will feel less inhibited in expressing tentative ideas. At the same time, the ways in which a teacher listens to students' contributions and responds by taking their ideas seriously and trying to build on them, can provide a model for students themselves to follow in discussions between themselves.

Overall, the important underlying principle is that all of us, whether as learners or as teachers, learn through involvement in discussion as well as through reading and writing. As Alexander (2006) puts it:

> Children, we now know, need to talk, and to experience a rich diet of spoken language, in order to think and to learn. Reading, writing and number may be acknowledged curriculum 'basics', but talk is arguably the true foundation of learning. (p.9)

5 Feedback on designs and products

Any feedback can be regarded as a form of dialogue. Thus, whilst feedback on written work or on a completed design or product may be on a different time-scale and more focussed on one-to-one interaction than feedback in oral dialogue, nevertheless many of the ideas developed in the previous section are relevant. In such contexts, feedback should be by way of comments which stimulate and help the learner to improve. Consider the contrast between the following (from Atkinson & Black, 2007) which could be about a task of designing a poster:

> *A nice picture but you need to add more detail*
>
> *'Your poster catches my eye but I am wondering why I should really want to recycle my rubbish! Can you persuade me? How about some imperatives? Some statistics that might encourage me to take action! What can I do? What should I do? (p. 207)*

The first of these simply tells the learner what is wrong, whereas the second gives ideas about how to improve and could set the learner on the path of thinking about how to develop the product. In general, a good comment should identify what has been done well and what needs to be done to improve, and should give guidance on how to go about making that improvement. One aspect of such feedback is that it can help the learner to come to appreciate the criteria of quality, to understand what counts a good design or a high-quality product: such appreciation and understanding are an essential requirement for attaining competence in any subject. It also follows that it might often be true that the submitted work, with the comments, should not be the end of the exercise: to achieve full reward from the time invested, the learner might well profit, from the opportunities presented by this investment, to learn further by implementing the improvements suggested by the comments.

What is less obvious, and more difficult for many teachers to accept, is that to give marks on a piece of work can not only be unhelpful *per se*, but can lead students to ignore the comments altogether. Indeed, there can be deeper harm in that a focus on marks can produce what researchers have called 'ego-involvement', an attitude in which both high and low attainers focus on comparing themselves with their peers, and which leads them to be reluctant to take risks and react badly to new challenges, because of the potential to encounter failures which might damage self-esteem. The opposite attitude can be described as task-involvement, in which learners believe that they can improve by their own effort, are willing to take on new challenges and to learn from failure. The evidence is that a diet of frequent marks can produce enhanced ego-involvement whereas if feedback gives only comments task-involvment is developed (Butler, 1988). Moreover, those with a task-involved mind-set become more competent learners in the future (Dweck, 2000). Many teachers find such a change hard to accept – but consider this comment from a teacher involved in the King's College work with schools:

> *At no time during the first fifteen months of comment only marking did any of the students ask me why they no longer received grades. It was as if they were not bothered by this omission. I found this amazing, particularly considering just how much emphasis students place on the grades and how little heed is taken of the comments generally. Only once, when the class was being observed by a member of the King's College team did a student actually comment on the lack of grades. When asked by our visitor, how she knew how well she*

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was doing in Science, the student clearly stated that the comments in her exercise book and those given verbally, provide her with the information she needs. She was not prompted to say this!
Derek, Century Island School (from Black et al., 2003, ch.4 p. 45).

This teacher and others involved with him also reported that after the reasons for the change to comment-only marking had been explained to them, parents were quite satisfied, and indeed were helped because comments suggest specific ways in which they can help their children improve, which marks do not do.

6 Self and Peer-Assessment

We regularly do peer marking – I find this very helpful indeed. A lot of misconceptions come to the fore and we then discuss these as we are going over the homework. I then go over the peer marking and talk to pupils individually as I go round the room.
Rose, Brownfields School (from Black et al., 2002, p.11)

This teacher was encouraging students to learn from discussion with one another, and in particular, in this case, from discussing the marking of one another's work. Students can be taught to recognise both quality and inadequacies in other student's work even if their own level of competence is different from the level of the work that they are reading. With teacher guidance that is focussed on clarifying the criteria for quality, students can thereby develop awareness of successes and problems in pieces of work and can articulate this in discussion. Where students do not understand the meaning of a target, or have little idea of what a piece of work that met the target criteria would look like, it may help to engage them in appraising existing technological designs and products: a concrete example can help to convey the meaning of criteria which are often specified in abstract terms, and thereby help them to apply such criteria to their own products.

Such peer-assessment can help students develop their self-assessment skills, for as students assimilate the criteria, they thereby learn how to assess their own work with greater clarity. The following short extract from a peer-discussion (Barlex et al., 2008) shows this process at work:

P1: This one's got the thickness about right. It gives you the crispiness and texture that the pizza base needs. The others are all a bit thick and have a doughy texture.
P2: Is that the thickness or the cooking time?
P1: The cooking time is going to affect the crispiness perhaps but not the texture. We need to roll them this thin next time.
P3: And we need to think about the thickness of the veg too. That one is too roughly chopped. It doesn't look good. Getting the slices thin and more the same… more uniform…will help the appearance and the feel of it in your mouth.
P1: So that's two thickness things we need to write down.
(p.22)

Developing effective self-assessment is an essential part of managing one's own learning. It requires the student to have a clear picture of the learning targets, to understand what would count as good quality work that might attain them, to judge where one stands in relation to those targets, so leading the student to acquire the resources needed to achieve them. The overall aim here is to achieve meta-cognition, i.e. the capacity to judge and steer one's own learning so that one can become a more committed, responsible and effective learner.

Given the potential contribution of peer-group discussion, it is important that teachers devote attention to helping students to work effectively in groups. The main rules recommended by Mercer et al. (2004) are that all students must contribute, that no one member says too much or too little, that every contribution is treated with respect and listened to thoughtfully, that the group must achieve consensus to resolve differences, and, finally, that every suggestion/assertion has to be justified – all arguments must include reasons. Work designed to help students implement these rules have shown that they can enhance learning. A similar and more comprehensive study by Blatchford et al. (2006) has produced similar lessons together also with evidence of improved learning. In the latter comparisons of control groups with trained groups showed clearly that the latter were more fully engaged in high level collaborative discussion, were less likely to have members who blocked group effort, and were more likely to sustain the topic than of wander off it.

7 Formative Use of Summative Assessment

None of the arguments set out above should be interpreted as an argument against summative assessment. Students, parents, teachers and their schools all need an overall review from time to time. The frequency of such summative reviews should be decided in the light of the purposes they are meant to serve. Such purposes might include:

- taking a decision about whether to continue with further study of the subject;
- communicating to those who will teach the student in the next module, term or year;

- providing general advice, even a wake-up call, to the student and to parents;
- providing school management and others with evidence about overall progress.

None of these requires very frequent assessments. It is generally true that summative assessments do not directly help to improve learning and indeed may inhibit it, as evidenced by the research quoted above by Butler and by Dweck, as well as by research on the affects of a test-aligned culture on students' motivation and self esteem (ARG 2002). In any case, a single overall mark or grade can give little help to learning because it can be achieved by many different combinations of strong and weak features. A profile assessment can be more valuable as it can enable these strength and weaknesses to be identified.

However, any summative assessment conducted by, and in full control of, a school and its teachers, can be used to serve both formative and summative purposes, and it would be a better use of the effort involved by teachers and learners in such work if this could be done. After all, the key difference between formative and summative does not usually lie in the task itself but in the interpretation given to the outcome. Thus, in a substantial project which requires several weeks of work, there may well be frequent assessments on a micro-scale which help improvement *en route*, with an assessment of the product at the end. In this final assessment, the students may learn from peer-group work in which they might assess one another's productions against the criteria, whilst at the same time the teacher can make overall judgments, using the same criteria – judgments which may be explained to each student in the light of their attempts to make such judgments for themselves. It may even be helpful to let students re-submit their work after such appraisals: some may argue that it is unfair to give such further help, but provided all are treated equally, this argument can hardly be valid, given that in everyday work, the capacity to respond to and benefit from critical assessment is an important asset.

8 Strategies

Sections 4 to 7 above explain several dimensions of formative teaching and learning. Whilst each of these needs attention, they have to be tried out within an overall plan to strengthen the formative aspect of classroom work. In this final section I suggest such a plan has to include two main features in the strategy. The **first** is suggested by the following statement by Perrenoud (1998):

> *I would like to suggest several ways forward, based on distinguishing two levels of the management of situations which favour the interactive regulation of learning processes:*
>
> *the first relates to the setting up of such situations through much larger mechanisms and classroom management. the second relates to interactive regulation which takes place through didactic situations.* (p.92)

The focus here is on the first of Perrenoud's two levels. Both in setting up classroom tasks and homework, and whether the tasks are practical or theoretical, it is essential to so choose and present any task so that it can provide opportunities for the incorporation of formative assessment interactions both between students and between the teacher and the students. This can involve, for example, thinking through beforehand the ideas and skills inherent in any task, and ensuring that it provides opportunities for students to think out essential criteria of quality for design and technology. In addition the assembly and sequence of tasks should be such that students have opportunities to work at the main conceptual and procedural aspects of design and technology in an ordered progression.

This last consideration leads naturally on to the **second** feature. Many departments have to use a carousel approach to cover the various aspects of technological work. If students are to experience a coherent approach to the development of their understanding of the nature of the subject, there has to be close collaboration in both curriculum planning and in day-to-day formative methods, with the strategy forged on a collegial basis between the different teachers involved.

There are additional reasons why such collaboration is important. Many teachers involved in the development of formative approaches have found the work both risky and very demanding, yet ultimately rewarding. The need that has emerged as top priority in such work has been for teachers to be given time to talk together, sharing their ideas and experiences, of both success and failure, and so learning from one another. Such sharing can be enriched if time can be found for observation, followed by feedback, of one another's classrooms. The mutual support within a common plan is in any case essential for some initiatives. Comment-only marking can only be adopted is it is a departmental policy, better still if it is a policy for the school as a whole, whilst students will find it strange, if not confusing, to be expected to engage in thoughtful discussion in one classroom and to then take part in an I-R-E ritual in the next. However, whilst the task is demanding, the rewards have been found to more than justify the effort. The strong evidence that standards of achievement are raised would be evidence enough. That something more important than this is involved was expressed by one teacher as follows

What formative assessment has done for me is made me focus less on myself but more on the children. I have had the confidence to empower the students to take it forward
Robert, Two Bishops' School (from Black et al., 2002, p.22)

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