The Dynamics of Group Learning

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Paper first presented at a meeting of the Kerala Department of Education: Towards a Global Competitive Learning Community – The Role of Active Pedagogy. Thrivananthapurum, India, January 2011

Introduction

Social constructivism dominates the literature on learning within the UK and underpins the notion of 'active pedagogy' in India. In this paper I shall discuss the limitations of social constructivist approaches in describing what happens within a classroom where there are a large number of young people interacting with a teacher and with each other. I will then draw on the field of complexity science to suggest how we might gain a deeper understanding of how learning takes place in groups of pupils than that provided by social constructivism. Following this I intend to draw on psychological and pedagogical perspectives to further develop this understanding of group learning. I shall place a particular emphasis on science education in the paper but the insights are applicable to the teaching of any classroom.

The Limitations of Constructivism

Piaget's work in the 1960s discussed the role of interaction amongst children in developing understanding (Piaget, 1995 [1965]). Interaction amongst children introduces 'disequilibrium' which forces them to consider the viewpoint of others and in this way to gain a greater understanding. As such, in the classroom, interaction between children is important in allowing this process of challenge by exposure to the understanding of others.

Whilst Piaget's view is considered as a form of *constructivism*, we should carefully distinguish between different understandings of constructivism in order to clarify its role in educationally theory. Whereas Piaget considered the interaction between peers, Vygotsky (1978) focused on the difference in ability or understanding of children as they interact, and his ideas are considered to belong to *social constructivism*. Vygotsky introduced the notion of a 'zone of proximal development' to describe the potential development that might take place when children interact. This refers to the difference between what a child might achieve unaided and what they might achieve with the assistance of a more able child or an adult. In teacher education within the UK much is made of the way guidance is altered as a child learns.

This form of social constructivism recognises the need for individuals to learn from those that are further in their learning in a particular field. They can learn the socially established procedures by which such a subject functions from discussion with those with greater insight into these. Whatever the subject being studied, social constructivism gives insight into how learning takes place when young people interact with each other and with a teacher (or with learning materials such as books etc).

However, Osborne attacks this conceptualisation of learning, arguing that constructivism:

> "has confused the manner in which new knowledge is made with the manner in which old knowledge is learned" (Osborne, 2006, p.53)

In relation to science education Osborne argues that learning through interaction does not give a comprehensive picture of the nature of science. The overemphasis on construction of concepts through discussion implies that the concept held by one child is more "viable" than that held by another. Science however, does not function in this way. Judgements should be based upon an empirical understanding of the world and Osborne suggests that the failure of social constructivism to acknowledge this leads to a limited understanding of science. Epistemologically, social constructivism emphasises the importance of entities constructed by scientists, for example the concept of the atom, or of the gene. Osborne argues that these are not separate from real aspects of nature as social constructivism might imply.

I agree with Osborne that there is a tendency for teachers to focus on discussion of concepts rather than the empirical evidence that supports them. Osborne himself was involved in setting the scene for 2007 changes to the school science curriculum in the UK (Millar & Osborne; 1998) which have gone some way to ensuring the primacy of empirical data as a way of supporting argument. However, this does not deliver a deadly blow for the use of social constructivism in understanding subjects such as science; a social constructivist might argue that whilst concepts are inherited from the past, they are still social constructs. Not only must a child accept the scientific truths being introduced in science lessons but must learn from others what these mean in the contemporary world. Even if we are to argue that science itself is based on unbiased consideration of empirical data (which itself is debatable) we must accept that learning the processes and established understanding of scientists must come from interaction with those that have an understanding of these.

There is an ontological issue here, in that we are saying that there is a real world that we interact with but also that our understandings of that world belong to some other 'un-real' world which is socially constructed. This invites a whole range of issues in distinguishing between the real and the not real and working out how they are related. I propose that we need to consider our ideas as every bit as real as the world around us and recognise that they are constituted of the flesh and blood of our bodies and brains as well as the symbols and even computer bits in which these ideas are manifested. That is an ontological discussion for another time however. Here I wish to draw attention to a more tangible issue with constructivist discourses, namely there lack of a voice when it comes to explaining what happens when we have a number of people in the room all learning at the same time.

If we were able to organise a classroom so that pupils were all learning in pairs, and the pairs were carefully selected so that one pupil was slightly more able than the other in the particular topic or skill we were hoping them to learn about, then Vygotsky's ideas suggest that at least half of the people in the room would be learning. Of course, classrooms are in practice not organised in this way for a range of reasons: attainment in different topics varies; we wish everyone to learn; there is interaction between pairs as well as within them; the teacher has an influence (beyond setting up the pairs); pupils may not learn from each other even if the zone of proximal development is optimal. We need to develop an understanding of how groups of pupils learn together within a classroom beyond simple interaction of two people.

There are a range of influences on the effectiveness of group work present within the pedagogical literature. Baines, Blatchford & Chowne (2007) looked at the collaborative group work of eight to ten year olds in science and found a broad range of collaborative skills associated with the amount and quality of support given in children explicitly developing these skills. This implies that the interaction amongst children is not simply a product of their relative understandings but is also influenced by the skills they have in utilising the information held members of the group.

This might be extended if we accept Bourdieu's (1986) notion that children of different backgrounds bring different 'cultural capital' to education systems and as such can achieve different things from those systems. Even if we do not accept the Marxist framing of it, this conceptualisation accounts for the relationship between pupil background and educational achievement that is well established (Chevalier et al, 2005; Blanden & Gregg, 2004).

Mercer et al (2004) refer to the importance of pupils talking and reasoning together in order to learn science. This presents a specific aspect of collaborative skills which will influence the effectiveness of group work and it is reasonable to assume that the linguistic abilities of the children in a group will also influence the learning in that group, whether discussing science or any other subject.

The individuals within a group then will differ in background, level of skill in collaboration, linguistic ability and understanding in the topic being taught. Beyond this however we must also recognise the dynamic nature of relationships and interactions within a classroom. These factors influence pupils every time they interact and those interactions are changing constantly within a lesson. Pupils interact with the teacher, those around them, sometimes those at the other side of the room, with books and other media, not to mention with the environment in the broadest sense: the weather; the wall displays; what is going on outside.

Social constructivism gives us a theoretical perspective with which to view the interaction of individuals. However it falls short of incorporating all the influences on this interaction. Furthermore, social constructivism cannot account for the dynamics of those interactions which are constantly developing within a classroom. Classroom interaction is inherently complex and we need an understanding of these dynamics if we are to understand classroom learning.

Complexity and Group Learning

Complexity science has been developing within the natural sciences over the last few decades, and is beginning to provide insight into the interaction of groups of 'agents', be they atoms, organisms or computers. Whilst I have elsewhere discussed the validity of applying such models to education (Hardman, 2011), I here wish to outline three possible insights which might be of relevance to understanding groups of pupils in classrooms: group patterns, network learning and unpredicibility.

Group Patterns

Complexity science is concerned with the development or 'emergence' of patterns from systems where the individual elements are seemingly disorganised.

For example, Wilensky's (1998) model shows that birds may form flocks by adhering to only three simple rules. Firstly that they tend to turn to fly in the same direction; secondly that they will avoid colliding through getting too close; but thirdly that they will tend to move towards each other (up to the limit of being too close). The model shows that with just these three simple rules birds that start by flying in randomly assigned directions in a simulated sky quickly coalesce into flocks which travel in the familiar triangle formation seen in nature. Undoubtedly this is a simplistic model but it demonstrates that the individual birds do not need to be organised by a lead bird or some outside influence; simply by responding to their immediate surroundings a pattern emerges and they form a flock. Wilensky's (1997) model of ant behaviour demonstrates how ant form lines between their nests and food by simply releasing and detecting chemicals associated with the food. Models such as these typify complex systems in which a large number of agents responding to the local environment result in patterns of behaviour on some other level of analysis.

Whilst there is continuing research and debate into how this might be applied to humans, the possibility that patterns emerge from localised interactions seems to fit with experience of classrooms in which the dynamics of interaction can change very quickly. Experienced teachers seem to be able to 'read' the patterns that emerge within classrooms and respond to them accordingly. We might speculate therefore that when people interact there are patterns of group learning which manifest themselves at a level on which teachers can respond to them.

Network Learning

Complexity science research is a broad field which provides other insights into what these patterns might be. Of particular interest here is the study of networks, which is proceeding at both the theoretical and technological level. Cilliers (1998) suggests that a neural network, that is, one that is made up of 'nodes' connected together by 'neurons', is able to respond to the environment and that this constitutes a form of learning.

Taking initial inspiration from neuroscience, technologists have been investigating systems in which the strength of the link between two nodes increases in relation to how often that link is used. This is known as Hebb's law in neuroscience. Computational neural networks have been developed which are able to process images, for example in number plate recognition (Draghici, 1997). To begin with, a system is given an input and the strength of the link between the nodes is adjusted until the desired response is required. For example, a computational network might be shown pictures of various different trees, from different angles and in various lighting conditions. Each time the network is adjusted until it gives some positive response to the image of a tree. The system is then able to recognise trees from further images, because the structure of the neural network is such that it has 'learnt' to recognise trees. What is more, a system that is able to continue adjusting the strength of neural connections can over time get better at recognising trees. There is research into how this might relate to our current understanding of brain structure (Bressler & Menon, 2010) and I have considered elsewhere whether human learning might be considered in this way (Hardman, 2010a). Networks research has also been applied to models of trade, mobile phone conversations, food webs and many other fields, all of which have shown that the networks involved are able to respond to some change in their environment.

What has this got to do with our understanding of group learning however? Well the implication is that not only do patterns emerge from group interaction, but the adaptation of the patterns might be considered as a form of learning. If we conceive of a class as a group of interconnected nodes, then we see that the organisation of the interaction between people will change over time. It is possible that the class *as a whole* might learn. Again this is highly speculative but relates to our experience of the classroom. If we consider the teacher as an external influence then we see that under the influence of the teacher the relationships between pupils will develop; the capacity of the class to learn will alter. The teacher does not dictate the exact dynamics of the class but is able to influence it such that it responds as a network.

Unpredictability

However, as we all know, the class may not respond in exactly the way we hoped it would. Complex systems are a subset of systems that can be described as 'nonlinear'. In linear systems, an input will have a predictable output because the input and output are linked by a mechanism that can be separated from the other factors affecting the system. An example of this is a pendulum, for which the motion is determined by equations linking velocity to the time it has been in motion.

In a nonlinear system the isolation of two variables is not possible. A double pendulum illustrates this well. If a second pendulum is attached to the end of the first, then when it is swung the double pendulum follows a seemingly unpredictable motion. This is a nonlinear system and the smallest influence on the system can have a large effect on the motion of the pendula in the future. In real systems this means that outside influences can have huge effects on the system. Whilst the equations of motion can be described by equations, a double pendulum in the real world will be influenced by the atmosphere and the precision of the materials it is made of, as well as what it is fixed to. This means in practice the double pendulum is unpredictable.

Elements within complex systems are intertwined such that influencing one might have an influence on the entire system. However, it may also have no influence at all. The dynamics of the system are affected by the links between the elements of the system and in turn those are determined by what has happened to the system in the past. This means that complex systems are unpredictable. Classrooms seem to also fit this description. The exact reaction of a class of young people to something is unpredictable; this is part of the excitement of being in classrooms. A child might bring a particular problem to a lesson which alters the whole dynamic of the class, or it might be windy outside, or there might be a visitor to the room, but the exact reaction of the class can be surprising despite the experience of the teacher.

Bringing these three insights from complexity science together we could put forward a speculative model that the relationships between pupils alter as they interact and that patterns emerge within classrooms not by design but by interaction alone. We could conceive of these patterns of behaviour as the class itself 'learning'. Yet we know this learning is not always predictable. At this point in time there has not been sustained research to fully consider whether we can consider classrooms as complex systems, nor to understand the implications of such descriptions. Whilst this is research that I am now undertaking, for the moment we must leave this as speculation. We can however look for support for this idea from other fields.

The Psychology of Group Learning

Bandura (1999) developed Social Cognitive Theory to account for how cognition functions in social settings. He notes that

> "Personal agency operates within a broad network of sociostructural influences. In these agentic transactions, people are producers as well as products of social systems". (Bandura, 1999: 21)

Applied to the classroom this means that the cognition of individuals is influenced by and influences the behaviour of the individual pupil, the behavioural patterns of that classroom and the environment (in the broadest sense). Whilst I shall not engage in a full discussion of Bandura's work in relation to education here I wish to draw some tentative parallels between this recognition of the dynamic interaction of individuals, behavioural patterns and the environment, and a complex social system in which these patterns of behaviour might emerge through the interaction of individuals with each other and the environment. Bandura's earlier work also suggests that this interaction might be as simple as one child observing the behaviour of another (Bandura, Grusec & Menlove, 1966).

So there is some cursory evidence that psychologists recognise the emergence of behavioural patterns from interaction, as viewing classrooms from a complexity lens would imply. What of the notion of the classroom itself learning though? Transactive memory might provide some support here.

> "individual memory systems can become involved in larger, organized social memory systems that have emergent group mind properties not traceable to the individuals." (Wegner, Raymond & Erber, 1991)

Wegner et al studied young adults in close, opposite-sex relationships and found that they were able to remember a list of objects better than pairs made up of strangers. This supports the concept that people who are close develop a system of memory that is superior to that of individuals and newly formed groups. Wegner et al were able to disrupt the transactive memory of the couples by giving them a system for remembering that they have to use, further implying that the mechanism for transactive memory are subconscious and develop naturally.

This seems to provide a theoretical basis for the stereotypical division of gender roles. Certainly my wife and I conform to the stereotype of her remembering birthdays and anniversaries and me remembering details of servicing our car. There is circumstantial evidence that this might apply to larger groups. In my experience of working at a university, there is a common understanding of who is the best person to ask on certain issues and where to go if you need a specific task doing. This is not quite the same thing, as there are established structures such as job titles that support this but I do not feel it is too far a leap for the concept of transactive memory to recognise both the formal and informal structures that arise over time to make an organisation more effective. Indeed there is much in the management literature about organisations self-organising (Stacey, 2005).

There is some support from the psychology literature that cognition, action and the environment co-develop to give rise to emergent patterns of behaviour. Furthermore, it can be suggested that groups subconsciously develop capacities greater than the aggregate of individuals alone. This gives tantalising support for groups of people conforming to what we expect of complex systems.

The Pedagogy of Group Learning

Science education in the UK has been utilising group work in a variety of ways for the past few decades. As such there have been a number of studies into its effectiveness. I will here draw on some of those studies to discuss what we already know about group work in classrooms, before considering what the complexity perspective might add to this.

I should note that the terminology in use in the UK is such that 'group work' usually refers to a classroom in which there are a number of small groups working reasonably independently. These might typically contain three or four pupils. My above discussion has not been clear about the size of the groups under discussion and this is in some respects deliberate as it is not yet clear whether complexity concepts can be applied to groups of this size, or whether we must consider larger groups only as complex.

The literature contains a lot of support for group work, if used effectively, improving attainment (Thurston et al, 2008). However, I often find these statements to be of little use to teachers who must make specific decisions about how to organise group work. We discussed earlier the influence of differences in background, level of skill in collaboration, linguistic ability and level of understanding of the topic being taught. Researchers try and focus on one of these influences during the course of research and as such are underplaying the nonlinearity of group interactions. This seems particularly true in the science education literature, perhaps because of the training of many teachers in linear science through their own education. There are however, some insights to be gained from the pedagogical literature, although they should be considered cautiously.

Within this paper I shall concentrate on the decisions that a teacher usually makes when organising small group work. Firstly whether the groups are heterogeneous or homogeneous will influence learning. A heterogeneous group may include different capabilities and also groups from different backgrounds. Watson (1992) argues that there is little clear evidence of the effectiveness of heterogeneous groups and this is because it is difficult to isolate the link between improved achievement and the heterogeneity in a group. A group may perform well due to the improved relationships between pupils rather than due to the mix of abilities and backgrounds of the pupils. Again, we recognise the nonlinearity of factors influencing performance.

Sampson & Clark (2009) conducted a study with 168 high school chemistry students in the USA. They compared the quality of scientific argumentation produced by groups made up of one high ability, one middle ability and one low ability pupil, to groups consisting of three similar ability pupils, as well as to individuals. They were surprised to find that in the mixed ability groups the overall performance was on average equivalent to a middle ability pupil working alone. This implies that there is greater benefit for less able pupils than for more able pupils from this type of collaboration. However, they also suggest that it is possible for a group to perform better than an individual on a task, but this does not necessarily mean there has been improved learning for the individuals in the group. Lower ability pupils might adopt an argument without understanding it.

Linking back to our model of complex interaction we might say that the group is able to perform better than an individual, but this does not necessarily benefit all the individuals. My own observation of lessons suggests that a teacher may ask ten questions and get ten correct answers from the class, but this does not mean the pupils all know the answers. Pupils will answer if they are confident they are correct. The group collectively outperforms the individual but we must be cautious as to the effects on the individual. Further relating this to transactive memory, we might propose that some members of the group carry more of the weight of remembering than others.

Heterogeneous groups seem to produce different learning from working individually. However there is no strong evidence as to which is better for pupils' learning. Of course, this is because the specific composition of the group and the nature of the specific task in hand have an influence. In their study Sampson & Clark (2009) draw on a broad range of studies to note that the benefits of collaboration are task and context specific. Complexity implies that the capacity of a group to perform one task by drawing on their internal organisation and external environment, does not mean they have the capacity to do a different task in a different setting. That capacity, as we have discussed, will depend on a range of things in a way that is not predictable.

So what are we to make of the pedagogical literature which deals with different types of group task? Again I shall draw on science education. In the USA, team tasks seem to have become an established part of the teaching of science (Watson, 1992). There are a variety of different forms of team task but essentially pupils in small groups compete against other small groups. This might mean a test score is given to the group as a whole, rather than an individual, or that some task must be completed by the group. In these team tasks however we must still consider the exact dynamics of the group carefully and cannot assume that the group are working together effectively. Kurth et al (2002) report on a case study of a group of 12 year olds working on a chemistry problem in the USA. They conclude that one of the pupils in particular is not able to engage with the discussion:

> Carla (an African American girl) was unable to hold the floor within the group, so her opportunities for science learning were diminished. The four students were not overtly prejudiced in their speech or actions. Yet the expectations they brought with them about how and when people should talk, how work should be done, and what standards of quality they should aspire to led them to reconstruct among themselves some of the most troubling inequities of our society as a whole. (Kurth et al, 2002)

There is clearly a cultural element to this that would be different in a classroom in India or the UK but nevertheless this case study highlights the need for the specifics of groups to be considered at length in setting up team task. Our earlier discussion of collaborative skills shows that they need to be developed over time (Mercer et al, 2004). However, even such explicit training in collaboration might not address the differences in the behaviour of pupils from different backgrounds, different linguistic abilities and different understanding of the subject.

Slavin (1996) notes that the individual accountability of pupils is important in ensuring success in team activities. Again, this may be truer in the USA than in other countries but the need for individual accountability has led teachers in the UK to move towards giving specific roles during group work. For example, in a chemistry investigation one pupil might be responsible for measurement, one for timing and one recording results. In a discussion, pupils play roles that are allocated to them. In practice teachers tend to use team tasks in which no specific roles are given for shorter tasks, to reduce the time setting up such activities. More involved tasks will have specific roles assigned either by the teacher or explicitly negotiated within the group.

What are the dynamics of learning in a group with specific roles though? Clearly, there cannot be an expectation that all pupils will learn the same thing. Indeed, some teachers deliberately use the assigning of roles as a form of providing different challenges to different pupils (something known as ‘differentation’ in the UK). If we relate back to our discussion of transactive memory once more, we might suggest that this interrupts the mechanisms for interaction that might have developed naturally within groups. However, if we consider the case of Carla presented by Kurth et al (2002) then we see that specific roles might enhance the involvement and learning of some pupils. This does render the interactions predictable however as there is still the possibility of inter-group dynamics affecting how the roles are played. Indeed, adult life contains both allocated roles and the flexibility of different modes of interaction within them.

As well as decisions a teacher makes about the composition of the group and the nature of the task there are more advanced forms of group work which bring a series of different modes of learning together. Slavin (1994) discusses a ‘jigsaw task’ in which pupils will move into specific ‘away’ groups, each charged with learning about a specific topic. For example, I have used this in my practice to teach about different forms of electricity generation. Once a pupil has a good understanding of one aspect of this, for example solar power, they return to their ‘home’ groups and teach the others about what they have learnt, as well as learning about coal, nuclear and wind power from group members who have been elsewhere. This allows pupils to learn about a specific aspect of an issue through unstructured team work and then work in groups where they hold specific knowledge to synthesise the information they have each developed.

With one of the classes I taught some years ago I assigned a colour, shape and number to each pupil. The shapes were what I believed to be grouping of similar abilities, the colours where mixed ability groups and the numbers where groups I felt would work well together in practical science investigations. Whilst this system was not perfect, at the time I felt it moderately successful as a mechanism by which I could quickly modify the nature of group interaction based on my awareness of the class and how individuals might work together. To do so I would simply ask them to get into their colour groups for example. Such practice represents a significant challenge to understanding the learning that takes place, as the group dynamics are being deliberately and abruptly modified by the teacher.

These more advanced classroom practices illustrate the limitations of our understanding of group learning. Whilst the pedagogical literature recognises that there is a difference between heterogeneous and homogenous groups as well as the need to think carefully about the way tasks are set up, there is no conclusive evidence around the relative merits of different strategies for group work. I propose that this is because group learning is a complex system which cannot be reduced to the analysis of isolated aspects of the situation.

Dealing with complexity

Whether groups are set up as heterogeneous or homogenous, whether tasks are given to teams working together as they see fit, or are broken into specific roles, it appears the exact learning that takes place will still depend upon a range of influences that are unpredictable. Yet teachers do seem to manage the learning of such groups, and at some level must be convinced themselves that group work is a useful aspect of teaching.

Davis and Sumara (1998) suggest that successful teachers are able to jump between different 'levels of complexity' in managing classrooms. The teacher might consider an individual pupil's needs, as well as the relationship between that student and another, as well as the requirements of the curriculum in planning an activity. Such teachers are then able to dynamically respond to changes in all of this in managing the learning activity. The difficulty with this notion is that it is almost impossible to support. It is nothing new to say that teachers deal with a lot at once, and this description of the cognitive processes of a teacher is at best indeterminable.

What I do take from Davis and Sumara's argument however, is the realisation that teacher experience is important, as is getting to know a class well. Whilst in schools it is generally understood that experienced teachers are able to mange learning more competently than less experienced teachers and that it takes time for relationships within a class to develop, complexity offers a reason for this. Experienced teachers are able to recognise patterns of interaction within classrooms and successfully manage them. This does not make classrooms entirely predictable, as these dynamics still change rapidly, but I have argued previously that the experience and intuition of teachers is important in this respect and should be valued more within education systems (Hardman, 2010b).

Conclusion

Constructivism tells us little about the learning that takes place in groups, either small groups within the classroom, or the classroom seen as a whole. Complexity science predicts patterns of behaviour, whole class adaptation and unpredictability that we see in classrooms and furthermore is supported by literature from psychology. The development of complexity science to understanding learning within classroom is still at a very early stage, and needs to be supported by a systematic evaluation of its application in the field of education.

The pedagogical literature has a variety of discussions of different modes of group work which are inconclusive with respect to the quality of learning that takes place in such situations. This is because we cannot extract cause from effect in a linear way; the classroom is complex. I have begun to show that with greater development complexity will provide a better understanding of the dynamics of these situations than social constructivism is able to, and thus reduce the gap between pedagogic practice and our understanding of learning itself. The clearest of these insights currently is that teacher experience and intuition is important in managing group work and that we should trust their intuition in managing the complex system of interaction within a classroom.

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