Improving the quality of science and mathematics education at universities has been a task to which governments and tertiary education institutions have committed. This was the case in Denmark at the end of the 1990s when the Danish Government, its Ministry of Research, and a network of Universities gathered efforts around the construction and functioning of the Centre for Educational Development in University Science. The centre established collaboration between seven Danish universities around the teaching and learning of science: Aalborg University, Copenhagen University, the Danish University of Education, the Pharmaceutical University, Roskilde University Centre, the Royal Veterinarian and Agricultural University, and the University of Southern Denmark. The centre operated during the period 1998-2001, thanks to the generous funding of 35 millions of Danish Kroner in total.

The Centre for Educational Development in University Science embraced a wide range of educational research and development actives through which the practice of university science education was addressed and improved. Areas such as mathematics, physics and chemistry education were central. The centre ran a Ph.D. programme, which enrolled 12 students who addressed a variety of educational issues in the subject areas of relevance for the centre. The centre also organised a series of conferences and seminars aiming at the professional development of teaching staff in the institutions associated. The centre financed a number of teaching development projects run by university staff in their own institutions and classrooms. Many leading scholars from around the world made important contributions to the work of the centre.

The present book emerged from the wide-ranging network of research and researchers, established through the Centre for Educational Development in University Science. The intention of the book, however, is not to provide any report of the research or developmental activities of the centre, but rather to contribute to the worldwide concern for analysing both challenges and possibilities for university science and mathematics education. Even if the book collects a majority of papers by Danish authors working in Danish contexts, the issues addressed by the different sections and chapters are of a general relevance for tertiary educational environments around the world. Furthermore, the dialogue between the Danish authors and leading international researchers in the field contributes reinforcing the broadness...
of the book for an international audience, in a changing world were transitions in
what is considered to be the core of science and mathematics education in
universities are taking place.

We want to thank all the people who have contributed to the completion of this
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Finally, we would like to dedicate this collection to the memory of Leone
Burton, a remarkable colleague and friend who during very many years supported
our work participating in some of the activities of the Centre for Educational
Development in University Science, conducting sessions with research students and
staff in Denmark, and being a critical partner in our previous work and in an early
stage of production of this collection. We are honoured to publish her paper, prob-
ably the last printed record of her proliferous and pathbreaking academic career.

Aalborg, May 2008

Ole Skovsmose
Paola Valero
Ole Ravn Christensen
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Introduction
The Multi-Layered Transitions of Knowledge Production and University Education in Science and Mathematics

Paola Valero, Ole Ravn Christensen and Ole Skovsmose

More than ever, our time is characterized by rapid changes in the organization and the production of knowledge. This movement is deeply rooted not only in the evolution of the scientific endeavour, but also and especially in the transformation of the political, economic and cultural organization of society. In other words, the production of scientific knowledge is changing both with regards to the internal development of science and technology, and with regards to the function and role science and technology fulfill in society.

Knowledge production has, for some time, stopped being the exclusivity of universities, founded as bastions and guardians of truth and knowledge. This production can now be owned by a variety of institutions and organizations with interests other than the production and maintenance of knowledge for its own sake. This general social context in which universities and knowledge production are placed has been given numerous names: the knowledge society, the informational society, the learning society, the post-industrial society, the risk society, or even the post-modern society (e.g., Castells, 1996, 1997, 1998; Beck, 1992, 1999; Lyotard, 1984).

A common feature of different characterizations of this historic period is the fact that we are living the beginning of its construction. Parts of the World, not only of the First World but also of the Developing World, are involved in the transformations associated with it. There is a movement from former social, political and cultural forms of organization which impacts knowledge production, into new, unknown and uncertain forms. Of course such an observation may be true for any point in time. However, the expansion of information technologies has created global flows of knowledge that implicate experts and non-experts in ways that have not been seen before. The accelerated pace of technological development and innovation opens so many options and possible, unexpected and almost uncontrollable courses of action that change, movements and transformations may go in different directions. Our awareness of the complexity of the changes in our time does not allow us to see a clear end. Somehow it seems that the clear-cut utopias that guided the ideas of development and progress in the past are no longer a strong presence, and therefore the transitions in the knowledge society generate a new uncertain world.

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In this context, it is difficult to avoid considering seriously the challenges that such a complex and uncertain social configuration poses to scientific knowledge, to universities and especially to education in the natural sciences and mathematics. It is clear that the transformation of knowledge outside universities has implied a change in the routes that research in the natural sciences and mathematics has taken in the last decades. It is also clear that in different parts of the world these changes have happened at different points in time. While universities in the “New World” (the American Continent, Africa, Asia and Oceania) have accommodated their operation to the challenges of the consolidation of the New World and, thereby, have had a more utilitarian concern, many European universities with a longer existence and tradition have moved more slowly into this time of transformation and have been responding at a slower pace to environmental challenges. The process of tuning universities, together with their forms of knowledge production and their provision of education in science and mathematics, with the demands of the knowledge society has been as complex as the general transformation that society is undergoing. Therefore an understanding of the current transitions in science and mathematics education has to consider different dimensions involved in such a change.

We find ourselves, and our universities, to be in a transitional period. In our choice of the term transition, we want to signal the idea that universities and their knowledge production and educational activities are undergoing a particular type of change. We did not want to adopt the term “reform”, since we do not want to convey the idea that changes intend clear improvement of the resulting state in relation to the initial state before the implementation of a change. We observe that current changes are happening at a variety of levels, from curricular plans, to administrative levels, and even at international regulations and harmonisations. It is clear that we are leaving “old” practices behind and are entering an era of “new” practices; however, the multiplicity of transformations blur the horizon of when changes will stop and where they will lead to.

Traditionally, educational studies in mathematics and science education have looked at changes in education from within the scientific disciplines and in the closed context of the classroom. Although educational change in the end is implemented in everyday teaching and learning situations, other parallel dimensions influencing these situations cannot be forgotten. The understanding is that the actual potentialities and limitations of educational transformations are highly dependent on the network of educational, cultural, administrative and ideological views and practices that permeate and constitute science and mathematics education in universities today.

1 Multiple Dimensions of Change

This book contributes to understanding some of the multiple aspects and dimensions of the transition of science and mathematics education in the current knowledge society. There is an increasing awareness of the fact that the actual teaching and learning of these subjects are influenced by much more than decisions related to the
very same development of the academic disciplines at stake. Social and political changes in recent times have triggered reflections about the role of science in contemporary, post-modern societies. Science and mathematics may not necessarily be conceived as disciplinary ivory towers existing inside the well-protected walls of universities. Such reflections have had consequences for the views underlying the provision of education in these fields.

Universities themselves have been the targets of administrative changes that intend to break the seclusion of knowledge production and put knowledge and education at the service of larger social, political and technological changes. These changes have also impacted the working frame for academic staff in relation to their research activities and, most importantly, in relation to their teaching activity. Science and mathematics education in universities are not immune to neither the administrative nor the cultural changes that may alter the space of teaching and learning.

We will analyze some of the complexities involved in these changes. We have defined four inter-related but still different dimensions of change that we consider necessary to understand the multi-layered transitions of university science and mathematics education.

1.1 Changes in the Processes of Teaching and Learning

First, we consider changes in the processes of teaching and learning. University education has symbolized a prototype of the broadcast teaching, where the person “who knows” has to present knowledge to those many students “who do not know”. Research in higher education has shown that this is still a dominant form of teaching, but many other ways of organizing educational processes are possible and, in fact, have been established (e.g., Knight, 2002). In opposition to the teacher-researcher as the center of teaching model, new forms of organization of learning advocate having students at the centre with strategies such as, for example, active learning processes around groups of students, or having students involved in the choice of study topics. These new approaches to teaching and learning deal with situations such as learning through communication and cooperation; learning of competencies rather than learning a fixed body of knowledge; the capability to address a broader contextual framework for scientific and technical knowledge as opposed to purely theoretical problems, etc. In Part I, we shall delve deeper into this type of transition in university education and we therefore start this book at ground level where the actual learning and teaching processes are the focal point.

In the late 1960s the students’ movement provoked an impact, at least in some universities in Europe. The broadcast teaching model, concentrated on specific content matter issues, was challenged by an anti-authoritarian approach to learning where students claimed the centre of attention and where social problems were the preferred starting point of any learning process. This activist approach to the use and development of knowledge was, in some universities, organized as project
work with the problem submerged and the students working in groups with the teacher acting as supervisor or even group member. Problem-based learning was one manifestation of this process and groups of students now produced large reports on real world problems as opposed to the formerly exclusively in depth studies of theoretical constructs. This anti-authoritarian approach also had implications for how the processes of learning and teaching was organized in science and mathematics education. The problem-based approach did not put emphasis on schooling into the traditions of a particular discipline. It was an interdisciplinary approach, which implied that disciplines merged together. Aalborg University, in Denmark, is an example of this development. Kolmos (Chap. 12) presents an overview of the experience of organizing university education in science, technology, engineering and mathematics in this particular institution. Aalborg University was founded on the activist principles mentioned above and based on the problem-based learning approach (PBL). Although the development of these ideas in practice has been very complex – and far from a smooth road – it has opened a space for mixing science and mathematics education with engineering, giving this new university of the 1970s a different profile from the older and often more traditional universities in Denmark.

There have been several phases in the development of the PBL approach. The first can be considered an exploratory one, where the original more political and radical view of education opened for new directions in university education. For instance, with respect to mathematics, a guiding idea was to pay particular attention to the applications of mathematics in real-life situations, and to the investigation of the functions of mathematical modelling in different contexts. A second phase was one of consolidation. Many routines were established. Examinations took a particular form. New students found both new educational practices that needed to be understood, and it was possible for them to find some traditions they could relate to. Teachers adjusted to play the role of supervisor and found their own way of managing the normally very time consuming supervision processes. Furthermore, the public critique of this “leftist form of university study” faded away. If one could talk about a third phase it could be characterized through the recognition of the efficiency of the PBL-approach. Thus broader empirical investigations indicated that candidates that had gone through a PBL-based university education had comparative advantages to their peers who graduated from traditional universities, when observed in complex work situations. A demand for professional scientists, mathematicians and engineers with a PBL-profile developed rapidly. The recognition of the PBL-approach has been further documented through comparative studies showing that education in a topic like mathematics was completed in a more efficient and competent way within a PBL-approach than within a traditional lecture format. The PBL-approach apparently squared nicely with the demands of the labour market in a knowledge society. However, many found that the price of this apparent success was too high, namely the renunciation of the political and critical elements so prominent in the first phase of the PBL-approach. Others, in particular at the early stages of implementation in the 1970s, found that the level of depth in theoretical knowledge dropped. These discussions in favour of and against PBL are all still
alive and are part of the make up of institutions where there is an organizational policy in favor of alternative educational forms. In that aspect the changes in teaching and learning practices related to PBL in Denmark do not differ much from other types of initiatives in other countries (Bowden, Chap. 9).

Today science and mathematics education are facing a huge challenge in forming a new idea and vision that can capture the attention of young university students. In some places the influences of the reforms of the 1970s are more vibrant than ever, while in other places they seem to be fading away. Thus the idea of conceiving students as central actors in educational processes in universities is still a very influential perspective. This involves allowing students to take initiative in their learning processes as well as enabling teachers to stimulate such initiative. Mason (Chap. 1) engages this discussion by making explicit the assumptions on which it is possible to envision a teaching and learning situation where people’s thinking power can be activated and activated into “productive ways of working”.

Another developing theme in teaching and learning processes today is assessment. New and innovative approaches to assessing science and mathematics courses that transcend traditional written or oral exams are studied more than ever (e.g., Poulos and Mahony, 2008). The importance of assessment as a main determinant of learning and teaching processes is illustrated by Grønbæk, Misfeldt and Winsløw (Chap. 4) who analyzed the effect of a teaching intervention, focusing on the impact that the designed assessment had on the evolution of the didactical contract between students and teacher in a third semester mathematics course. The renegotiation of traditional expectations and learning activities – what counts in order to obtain a good grade – is one of the most interesting observations in this study. There is the hope that, as changes in assessment occur in other classrooms, the renegotiation of the traditional university didactical contract will become a noticeable phenomenon beyond the particularity of this classroom.

Troelsen (Chap. 3) and Eriksen (Chap. 2) further exemplify what such engagement could look like. Troelsen explores the meaning that laboratory work in chemistry education could have, theoretically and in practice, if reflections about student competencies are taken into account. In a “reflective society of knowledge” laboratory work should contribute to the development of analytic and cooperative competencies that cannot be secured by traditional, procedural and syllabus-oriented laboratory work. The concept of competencies becomes central in a design of alternative laboratory practices for students. Krageskov Eriksen is concerned with the social role of science in a context of reflective modernity and of a risk society. A key concept for understanding the development needed in science education to match this (changing) social role of science is reflectivity. Therefore, Eriksen proposes an operationalization of this concept in a manner that renders it constructive in the tertiary science education context, more particularly, in chemistry education.

Hence, in the first part of this book, different perspectives on the recent and future developments in learning and teaching processes at universities are discussed, hence contributing to the development of new visions for the learning processes in science and mathematics.
1.2 Changes in Academic Cultures

Secondly, we consider changes in academic cultures in universities. The notion of academic culture refers to the espoused priorities and discourses which set the scene for educational priorities in relation to the academic communities involved in transformations (Hasse, Chap. 5). Which views of knowledge and science underlie the way academic staff engage in educational processes? What is considered to be relevant to bring into science and mathematics education? What is considered legitimate scholarly criteria for scientific and educational quality? What are considered to be collective principles for teaching and learning? Who defines such priorities? Culture, understood in the broad sense as a set of collective values which are constructed through and which simultaneously emerge from practice, becomes an important category for understanding the transition in science and mathematics education. In university settings, different academic cultures overlap, integrate and also conflict with each other.

According to Snow’s Two Cultures (published first time in 1959), two cultures of knowledge production seem to drift apart in the Western World. Snow refers, on the one hand, to the culture of the humanities and, on the other hand, to the academic cultures developed around the natural sciences. He describes how this cultural division was acted out even at high tables at the colleges in Cambridge. The topics for the dinner talk were completely different, depending on which of the two cultures was setting the scene. It was not easy to establish any dialogue across this cultural gap. One could assume that this cultural gap was a Cambridge phenomenon, but it appears to be running across all university campuses. Snow sees this cultural gap as a problem of the “entire West” and he believes that “the intellectual life of the whole of Western society is increasingly being split into two polar groups” (Snow, 1969, p.3). As we will see the situation might turn out to be much more complex.

The gap between the way in which the world is conceived from the perspective of the humanities and from the natural sciences establishes a profound condition for today’s educational changes, at least in some parts of the world. Hasse (Chap. 5) really goes into the depths of the study of the culture of professional university physics in the Nordic countries and in Southern Europe. She shows how, in Northern Europe – Scandinavia and also the UK – physics is considered masculine and incompatible with human science. The discipline is placed in an untouchable ivory tower of “hard elitist science”. This finding resonates very well with Snow’s cultural divisions of the corridors in the traditional British universities. The situation, though is quite different the further South and East one goes: “In the Southern part of Europe general cultural conceptualizations of physics seem much less connected to gender. Physics is more integrated with the general cultural history and is not seen as a particularly “hard discipline”. Hasse’s analysis leads her to wonder whether challenging an internalist view of science and acknowledging its embeddedness in culture could open possibilities for envisioning new more gender-sensitive, responsible ways of doing science. The result of such other forms of science
could eventually be breaking the gap of cultures in universities, a point also shared by Harding (Chap. 14).

It is clear that many of the issues related to the cultures of science and mathematics reside in the characteristics of the internal practices of those who do research and teach in these areas: the university staff. An important element of innovations and changes in the way the disciplines reproduce themselves both in research and in the education of the younger generations concerns the education of academic staff. The disciplinary training and expertise of staff in their particular field of research is one of the dimensions at stake here. However, that dimension is not the focus in this book. Rather, we are interested in the qualifications that elate to the staff’s competence to lead educational processes for their students, and their ability to engage the breadth and complexity of the teaching situation. This engagement involves discussions on the pedagogical priorities of the academic staff including their conception of good teaching and proper university education. Kruse, Nielsen and Troelsen (Chap. 8) exemplify views among university staff about what constitutes good teaching, and highlight five interconnected points: Mastery of and strong knowledge about the subject matter, mastery of pedagogical skills for communication, management of interpersonal relationships, connection between research and teaching areas, and position of a favorable personality for teaching. An interesting question to pose to this finding is the extent to which these five points reflect the priorities and values of academic cultures, and how these points emerge as a type of shared idea of good teaching among young university staff.

However, there are many more cultural issues to be aware of in relation to university education. One could argue that academic cultures are influenced by external pressure from a business culture that talks the language of “surplus”, “productivity” and “effectiveness”, while university staff would rather talk in terms of “truth”, “insight” and “knowledge”. In addition, the culture of globalization has also created a new international cultural mix, which challenges the previously national perspective of universities by the demand for internationally targeted education, and by the need to attract students from all over the world to programmes of study. One could mention the emergence of a new youth culture, which adds to the cultural diversities within universities, when seen from the perspective of the diversity of competencies, interests and expectations that students bring into their studies. It is certainly necessary to talk about different cultures at the university, but hardly about just two cultures and one gap. It seems to be more appropriate to talk about numerous sub-cultures and several cultural gaps when we engage in university education studies today.

An example of another cultural gap concerns the differences between the science and mathematics learning cultures and the workplace culture that students will later on engage with. Here the central issue might be thought of as differences in general working conditions. The time schedule for studying may be quite incomparable to a work-place schedule. What might be a good solution in the academic culture may be highly problematic in a workplace culture, for instance, with respect to consumption of time, resources used, patents owned etc. Furthermore, the differences in academic
and workplace cultures can also be acted out in very specific ways. For instance the ability to use a certain concept or technique may be quite dependent upon the particular context of its use. Some criteria could dominate the academic use while quite different ones may be applied in a workplace context. Roth (Chap. 6) presents an elaborate example of this phenomenon where he addresses the issue of whether it is feasible to suppose that key scientific competences such as reading graphs is a general abstract competence that can successfully be put into operation in any kind of graph-reading situation. His research with scientists in universities and in workplaces shows that graphing competences are highly dependent on the work practices people engage in. Here the term “work” also applies to the work environment of scientists in universities and their practice in a particular field of knowledge. Roth’s analysis reveals clearly that scientific work, thinking and competencies are as immersed in cultural practice as any other type of activity and practice one could think of. Roth calls for the need to turn university science education so that it becomes possible for students to develop practice-bounded “knowledgeability”.

With respect to a particular scientific discipline it is also possible for cultural gaps to emerge. On the one hand one can consider how researchers within a field of study are formulating new theories and constructing new knowledge. One could talk about “logic of discovery”. On the other hand, one could consider how the curriculum is structured within university courses. This structure reveals “logic of representation”. These two logics are different and it is often claimed that they have to be so. Thus, it is pointed out that the student must come to master the discipline through “logic of presentation” in order to, later on, be able to master “logic of discovery”. This cultural split within a discipline has been pointed out by Burton (Chap. 7) with respect to mathematics. Burton differentiates between the “culture of mathematics” – the aspects of mathematics which are identifiable as discipline-related and that are part of the value set that a participant in that culture needs to be acculturated into – and the “mathematical culture” – the set of socio-political attitudes, values and behaviours that, in situations of communication around mathematics, shape how mathematics practitioners experience mathematics. The very interesting observation emerging from Burton’s work is the fact that there seems to be contradiction between what mathematicians express about the culture of mathematics and what can be observed about the mathematical culture. A great challenge for groups of mathematicians in universities is, therefore, to transform their communication practices around mathematics, particularly in the settings of teaching and learning of new apprentices of mathematics, if a more accessible, “humanistic” mathematical culture – to borrow Hasse’s term (Hasse, Chap. 5) is to be developed in universities.

1.3 Structural and Administrative Changes

Thirdly, we consider structural and administrative changes. Hence, we take a step back and try to understand why and how universities are under structural and administrative transition. Universities have a long history, and, at least previously,
they have taken up the position as society’s most sublime centre for knowledge production. In the classic university, associated with the Humbolditian tradition, the main aim was to produce knowledge, and to do so independently of particular interests be it religious or economic. The practical aspect of university production was associated with the graduation of candidates, who could, on the one hand, bring knowledge to the world outside the university, and, on the other hand, feed the reproductive system of academia. Today the picture is much more complex, and new demands for the type of knowledge to be developed by universities have come to play a decisive role in the organization of knowledge production and education. Krogh (in press) analyzes the current wave of transitions in European universities, within the context of the general frames for the development of Europe, within the global, informational society. First, Krogh notes that the European Union has given the university a very clear role in relation to economic growth:

The knowledge economy and society stem from the combination of four interdependent elements: the production of knowledge, mainly through scientific research; its transmission through education and training; its dissemination through the formation and communication technologies; its use in technological innovation. At the same time new configurations of production, transmission and application of knowledge are emerging. [...] Given that they are situated at the crossroads of research, education and innovation, universities in many respects hold the key to the knowledge economy and society (Commission of the European Communities, 2003, p. 4, cited in Krogh, in press)

The Bologna Declaration (European Ministers of Education, 1999) has been preparing the terrain for the realization of the vision expressed in 2003. A reform towards transparency and quality that can secure mobility of students between European universities has been complemented by a series of European initiatives supporting changes in the administration and competitiveness of universities. It is in this scenario that current transitions, at least in Europe, could be understood. One example of these structural changes is the reform of leadership and administration. “Old European” universities have a long tradition for a certain degree of democratic organization. The heads of departments, the Dean and the Rector have normally been elected among colleagues, which establishes a degree of collegial solidarity. However, the trend of new management has established new procedures and accountability systems: the Rector has to be appointed by a board of trustees; the Dean by the Rector; and the heads of departments by the Deans. This top-down structure has serious implications for the organization of both the content and form of the university education, as Horst and Laursen (Chap. 10) illustrate.

This new structure is reflective of a clear alignment with economic and industrial interests, as discussed above. As a consequence, research at universities becomes measured in terms of newly invented scales of productivity. New accountability systems, meant to measure the effectiveness and productivity, are set in operation. These systems identify a way of carrying out input-output analysis. The input can be measured in terms of money allocated to the different institutions, research programmes, research groups, etc. The tricky thing becomes how to measure
the output of academic activity. A first manageable but rough measure would be to turn output into numbers of publications written, the number of students going through studies successfully, the amount of Ph.D. degrees conferred on time, the amount of money raised for research purposes from private funds, etc. When one can measure output, then one has established a better grip of managing research and education according to business principles. When research becomes to a larger extent financed by industry and institutions with particular interests, it is not surprising that a management turn is taking place. This turn reveals an intensive interaction between power and knowledge. It is a turn, however, that has not been requested by the research or educational communities.

Science and mathematics education at university level is now operating within a complex set of interests, which really stress what to include in the curriculum. This demand is being set in operation, at least in Denmark, by correlating the funding of the universities with the degree to which the candidates from the universities find jobs. Furthermore, there are huge demands for labelling students and candidates according to their competencies, which should be declared in a way that is transparent for the (international) knowledge market – in the European sphere according to the criteria of the Bologna Declaration.

In his reflections on the structural university reforms that he has witnessed during the last 30 years in Australia and some other English speaking countries, Bowden (Chap. 9) points to the fact that none of these changes have resulted in any substantial improvement of the educational settings that students experience, even though the initial justifications for most of these changes are precisely the improvement of quality of the provision of education. The reason for this might be that many of the external structural demands, which we have described above, obstruct qualitative improvements in university science and mathematics teaching, rather than promote significant betterments.

Laursen and Horst (Chap. 10) present a particular and local example of how a structural reform has been implemented in the Faculty of Sciences at Copenhagen University, and they discuss to what extent its results have been beneficial for creating better frames for student learning. On the other hand, Rump and Winsløw (Chap. 11) argue for the need of educational reforms that have a lasting impact. They consider how tertiary didactics can be beneficially implemented in a Faculty of Science by a combined local and global approach.

1.4 Changes in the Conception of Science

Fourthly, we consider changes in the conception of science, in particular concerning the relationship between scientific development and social development in general. From the perspective of Modernity, one could claim that science and mathematics especially stemming from university departments represent genuine knowledge that will emancipate humanity from traditional and religious pre-scientific knowledge and belief systems of the past. This is the narrative told by the Enlightenment
Movement and by social theorists such as Karl Marx and Georg Wilhelm Friedrich Hegel. However, the role of scientific knowledge in society now appears much more complex, and we witness social uncertainties and risks which might be produced by science. We experience how science gives multiple conflicting answers to many questions, and we are constantly faced with scientific inventions that while being effective in one area have less beneficial side effects in others. Many of the chapters in this book address these issues, since they are at the background of the educational, cultural, and structural changes in university science and mathematics education.

Scientific knowledge is in a transitional period from originally being something shared as everybody’s property for the common good of humankind to being a protected product, for instance through rules of patenting, in order to be distributed to the market. This transition does not only suggest that university faculties put a price on the knowledge produced. The changes are much more radical as the very organization of university research and education are being transformed. Knowledge that is usable and can perform in practice will win the competitive race for research funding. This means that the emergence of “new sciences” (like nano-science, health-science etc.) finds new prosperous ways of challenging – and sometimes even displacing – the old academic disciplines in university structures and changing them into competitive fields of research – probably engineered by the vision of the EU mentioned above (Commission of the European Communities, 2003). In the early 1970’s Jean- François Lyotard was one of the first thinkers to recognize this development. He termed it the “postmodern condition” for knowledge (Lyotard, 1984). Whether or not the change should be termed postmodern, there is no question that we are witnessing a dramatic change in the conception of science. The assumed everlasting knowledge, as developed by the geniuses of the break through of Modern Science like Isaac Newton, Johannes Kepler and Galileo Galilei, is no longer the prototypical form of scientific development. Instead, new products for the market that are made available through technological innovation are what constitute the power of science. The “new sciences” are part of this process and suggest deep conceptual transformations in our understanding of what science and knowledge are (Christensen and Hansen, Chap. 13).

One of the assumptions of Modern Science, which has provided a protecting myth, is that science and mathematics are operating in a neutral domain guided by the criteria of quality of pure research. However, we are in a situation where we must acknowledge the complexities of knowledge fabrication in relation to all kinds of social, political, economic and even cultural interests (Harding, Chap. 14). The classic discourse about the internal qualities of research is challenged by a discourse about research productivity. The big issue at stake is whether scientific cultures within universities are being consciously responsive to the challenges that such change represents to the conceptions that science practitioners themselves hold about their scientific endeavour. One of the points that scientists and researchers on the sociology of science have under-estimated is the consequence of the dominance of Western, androgenic assumptions in science. Gender studies in science – such as Harding (Chap. 14) and Hasse (Chap. 5) – can still interrogate the role of the scientific enterprise in the world today.
Another different but related issue is whether these changes impact educational possibilities and conceptions in mathematics and science studies. Skovsmose (Chap. 15) argues the need for a “critical professionalism” to be part of university studies. Critical professionalism refers to the awareness, on the part of the science practitioner, of the connections between particular fields of knowledge and other fields, of the fact that scientific and mathematical knowledge are bounded to social action, and of the ethical dimensions of producing and applying scientific knowledge. Critical professionalism for Skovsmose is one of the main competences of scientists in a time of uncertainty. This observation resonates with Bowden’s observation (Chap. 9) about the need to generate in students a capacity to tackle not what is known and familiar, but what is unknown, uncertain and, probably, unpredictable.

2 About This Volume

As seen above, the current transition in university science and mathematics education is a multi-layered process where changes are happening simultaneously across several dimensions and in several spaces. Covering such a vast landscape exhaustively would be almost impossible. Therefore, when organizing this volume we did not envision an organization that could represent a logical flow of argumentation through the different chapters. We collected a series of papers that based on particular experiences in particular contexts, open critical points of debate about the multiple predicaments that university science and mathematics education face at the moment.

The fact that most of the authors belong to Danish universities does not bind the discussions raised to the context of Denmark. We have invited authors to transcend national boundaries and to link their experiences to more general trends that are common to many other countries in the world, and to many other university environments. The conversation with experienced researchers in science and mathematics education in Australia, Canada, the United Kingdom and the United States broadens the perspectives presented in the collection.

Finally, we have spoken generally about science and mathematics education. Nevertheless in this book we address more directly three classic domains of university education, namely, mathematics, physics and chemistry. We let “science” function as a general label, being well aware that one could claim the importance of making a distinction between, on the one hand, mathematics as being a formal science, and, on the other hand, physics and chemistry as belonging to the natural sciences. The considerations and reflections in this book might in many cases be more general, and therefore be pertinent to other domains such as biology, computer science, statistics, bio-chemistry, etc. We are well aware that a claim of generality can always be contested by other observations. But we take that fact as a compliment if, reading this book generates further reflections about the transitions in other fields.
References

Part I
Changes in Teaching and Learning
Chapter 1
From Assenting to Asserting

Promoting Active Learning

John Mason

The issue addressed in this chapter is age-old: How can learners be stimulated to move from *assenting* (passively and silently accepting what they are told, doing what they are shown how to do) to *asserting* (actively taking initiative, by making, testing and modifying conjectures, and by taking responsibility for making subject pertinent choices). How can learners be provoked into actively working on and making sense of the ideas and techniques that they encounter, and how can this cultural ethos be fostered and sustained?

I use the term *asserting* because of the assonance with *assenting*, but also because it signals that the learner is taking initiative and making significant choices. It is not intended to indicate that learners become either arrogant or garrulous. Much of the most desirable *assertive* behaviour is internal, and need not have visibly overt external behaviour. It involves taking initiative, taking control, making choices, and becoming independent.

One of the reasons often given for assenting or passive stances taken by students is the fact that they are immersed in a culture of testing, so that their focus is on being told what they have to do to pass the next test. In other words, it is to be expected that in a culture of testing you get test-oriented (assenting, passive) behaviour. However, in this chapter the claim is made that it is perfectly possible to develop a culture of seeking to understand, and more, a culture of enquiry, within any testing regime. The way to do this is to evoke, support and develop learners’ use of their own natural powers of sense making.

The chapter describes some of the most fundamental powers which all learners possess and have already used before coming to class, but which may have been put to one side due to previous experiences of being taught which failed to make use of these powers. Identification of these powers comes from reflecting on personal experience informed by the seminal insights of Pólya (1962) and Gattegno (1970) and developed over many years since Mason et al. (1982). The chapter also suggests tactics which have been used by teachers to get learners to make use of those powers, in contrast to teachers unwittingly doing the real work for learners, whether in plenary sessions, in tutorials or in informal learner discussions through an unconscious
decision to “push things along a bit”, “get to the end of the lesson on time”, or “helping learners to understand”. The tactics are equally applicable to lectures, tutorials, problem-based sessions and the use of Information Communication Technology (ICT). In each case there are forces acting to increase passivity that need to be countered through suitable choice of teaching tactics and the development of a culture that overtly values learners taking initiative.

Promoting active rather than passive learning can be expressed in terms of the development of personal agency and identity. The chapter draws upon studies of similarities and differences between Confucian and Western views of education to try to locate a common core of personal agency, which straddles the two traditions.

1.1 Assumptions

Before describing powers and strategies, it may be helpful to articulate some salient assumptions on which the chapter is based.

1.1.1 Assumptions About Human Beings

Human beings are seen here as naturally active construers of the sense impressions which they experience. They possess not only fundamental powers for dealing with these impressions, but also a fundamental curiosity or drive to want to make sense of them. When learners are encountered who seem to want to sit passively and learn by rote, then it is because they have been trained or acculturated to act this way. Nevertheless it is still possible to engage such learners, to provoke them into activity, by refusing to amplify their tendency to want things packaged and painlessly injected. Instead of trying to “do the learning for them”, teaching can be exciting and stimulating by taking as its core purpose the provocation of learners to activate, become aware of, and develop their natural powers through encounters with pervasive mathematical and scientific themes.

This chapter takes an overtly constructivist stance, combining aspects of both psychological and social constructivism. Learners are seen as active agents (though the level of activity may be below desired thresholds!) whose psyche consist of the interweaving of behaviour (enactive), emotional (affective) and intellectual (cognitive) strands through the exercise of will, and who are embedded in a social milieu in which colleagues and teachers display practices which are adopted and adapted by learners.

1.1.2 Assumptions About Cultural Heritage

Covert activity, in which the learner is assembling and internalizing what is being offered so as to engage deeply with it subsequently is all too easily confused with
actual passivity, in the sense of “waiting to be told what to do and explicitly how to do it”, and “taking as little initiative as possible”. For example, in the Confucian tradition, “human self-perfection [is] pursued as the highest purpose of life through personal commitment to learning” (Lin, 2004, pp. 129–130). Whereas in the West, rote memorization is seen as an end in itself, an attempt to minimize effort and simply regurgitate what has been “taught”, the Confucian heritage sees commitment to memory as simply the first of a sequence of four phases. Memorized passages are interrogated for intention, style and meaning, and then applied to other situations in order to test it out in experience. This moves into critique and modification so that what was “memorized” is internalized and integrated into the learner’s functioning (Lin, 2004, p. 131).

At the heart of both Western and Confucian heritage approaches to teaching and learning lies initiation into productive “ways of working” on science and mathematics, whether in the classroom or in the world outside. The tactics proposed in this chapter serve to activate and intensify activity corresponding to the later phases of the Confucian approach, but right from the beginning without depending on an initial phase of memorization.

### 1.1.3 Assumptions About Mathematics and Science and Their Didactics

Mathematics and science, as bodies of knowledge occupy what Popper (1972) called the “third world” of accounts lodged in libraries. However, these accounts are at best the expression of how someone else’s attention was altered in its structure. They indicate subject specific sensitivities to notice and dispositions to act, and characteristic ways of acting. What the authors attended to, and how they attended, are evidenced only through what they were then able to express as a result, through the manifestation of their behaviour, itself usually refined and distilled. To make use of these accounts it is necessary for readers to experience transformations in the structure of their own attention, even if only vicariously and in their imagination.

Mathematics and science are both seen here as activities, as ways of thinking and acting in the world. Facts and figures are accumulated and rehearsed while engaging in pertinent activity. While learners sit passively, accepting and assenting to what they are told or shown, taking notes to “learn” later, they are not actually doing mathematics or doing science. Certainly they are not developing their powers of thinking mathematically and scientifically, to make mathematical and scientific sense of the world.

How then can learners be provoked into taking initiative, into making use of and developing their natural powers, into anticipating what is coming rather than rushing to catch up with what is being written on a screen in front of them by an expert? How can they be acculturated into developing both disposition for, and familiarity with productive ways of working on scientific and mathematical phenomena?