THE INFLUENCE OF NATIONAL CURRICULUM REFORM ON TEACHERS’ ATTITUDES TO AND PRACTICES OF MODELLING, AS MEDIATED THROUGH THREE DIFFERENT IMPLEMENTATIONS

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England and Wales implemented a national curriculum reform in 1993: for the first time modelling and problem solving were made a compulsory component of all pre-university academic 16-19 mathematics examinations. The most important reason advanced for implementing modelling and problem solving is its effect on enhancing attitudes and hence encouraging participation and motivation. But in practice, there were a variety of interpretations and hence implementations of the reform. This paper reports a cross-sectional study of the effects of three different implementations on teachers’ attitudes to modelling, as measured by specially constructed questionnaires and validated in interviews and observations. Significant variations were found and investigated. Some significant student differences were independent of those of the teachers, suggesting a reform-effect that is not reducible to the teachers’ attitudes.

Introduction

This paper reports the effects of a particular national curriculum reform on the teachers involved in its classroom implementation. Reform of the curriculum is known to be afflicted with problems of implementation: the original intentions of the initiators are often lost as a reform reaches wider social groups who make their own sense of it (Kyeleve, 2006). For top-down reform it may be the norm that initial intentions are distorted. With respect to USA 'reform' prior to the NCTM Standard in comparison to Japanese mathematics reform, Stigler & Hiebert noted that:

"Regardless of whether Japanese classrooms share features of 'reform' classrooms or not, it is quite clear that the typical US classrooms do not. This is especially interesting given the fact that the US teachers … reported having read the NCTM standards. Seventy per cent of the teachers even claimed to be implementing such ideas in the very lesson that we videotaped." (Stigler & Hiebert; p. 19).
Recent emphasis in USA mathematics classroom practices post-NCTM standards seems to have shifted focus to Chinese way of learning mathematics, especially those of Singapore (Lianghuo, et al., 2004). Essentially the problem is one of interpretation and implementation. A curriculum statement may mean nothing without a coherent examination or assessment scheme which accredits it. An apparently coherent curriculum and assessment scheme may mean little without supportive materials and teaching guidance on strategies which may make it three-dimensional (Treffers, 1987). And to this one could add that it is necessarily transformed by the attitudes and interpretations of it which teachers and students bring. A key question then is: can curriculum reform from above be authentically implemented, and if so under what conditions?

The study reported here was fortunate to gain access to three different but parallel implementation programmes of a more or less top-down compulsory national reform. The national reform took the form of a government specification requiring that all courses should include 'mathematical modelling'. Its content includes:

* Understanding the process of mathematical modelling with reference to one or more application areas.
* Abstraction from the real-world situation to a mathematical description.
* The selection and use of a simple mathematical model to describe a real-world situation.
* Approximation, simplification and solution. Interpretation and communication of mathematical results and their implications in real-world terms; and progressive refinement of mathematical models. (SCAA, 1993)

Clearly this involves many skills not exclusively mathematical, such as the social skills of teamwork, listening and communication. But there are specialist mathematical elements even of these. Mathematical communication and comprehension are clearly not just the union of mathematical skills with communication skills. It is argued that even social skills need to be specifically developed within mathematical contexts so that inappropriate beliefs about the nature of mathematics can be addressed (Schoenfeld, 1985). In other words, it is argued these skills must be taught as an integrated part of the mathematics curriculum.

Following the modelling content prescription, each implementation programme had its own examination structure of tests and assessments which had to satisfy the government's criteria, but had several other differences, for instance the amount and type of teacher training support available, the means of assessment introduced, and the tailored materials and texts provided for the classroom. But most importantly, each programme was adopted by the schools and teachers selecting it from a range of alternatives. Each implementation can therefore be viewed as the result of the engagement of a particular school culture with one of these parallel implementations, each of which was supposed to carry through the reform. One programme, however, which is termed 'traditional', interpreted as basically a reaction to the reform: it met the requirements in the most minimal fashion. The teachers and schools adopting this implementation generally wanted to limit the effect of the reform on their teaching, and especially on the assessment scheme. The other two programmes were apparently consistent and wholehearted reforms, but they differed in significant ways.

Of course, it is impossible to disentangle the reform, its implementations and the teachers' attitudes to them. It might be said therefore that the study is essentially three case studies in one. However, some variables and factors in the investigation were isolated, by developing instruments that measured teachers' beliefs about and perceived practice of
mathematical modelling. A number of components of attitudes emerged from factor analyses, validated through interview and observational data, and these provide a structure with which to differentiate the attitudes of teachers involved with the three programmes. Some expected differences do indeed emerge, but there are some surprises too.

**Background**

The background to this study is a national reform in England and Wales through a change in the examinations for mathematics required for university entrance in most science subjects. The focus of this reform was the field of 'mathematical modelling and problem solving', which has a particular history in the UK context with a pragmatic trend that places emphasis on utilitarian or pragmatic goals as opposed to the “scientific-humanistic trend, but which can be best understood as a means to motivate mathematics education amongst students and teachers. As in many other parts of the world, mathematics educators in the UK have appealed to the importance of mathematics for practical, applied problem solving skills when attempting to justify its central place in the curriculum (Blum, 1993; Blum & Niss, 1991; Burkhardt, 1989; NCTM, 1989; Niss, 1987 & 1989; Usiskin, 1989 & 1991).

Early attempts to develop modelling and real problem solving courses were based in the university degrees, but even in the 1970s experiments were attempted in school curricula (Ormell, 1971) and some chapters about modelling entered the mainstream texts. The fact that these early attempts were marginalised was essentially due to the failure to build the assessment of modelling into the formal accreditation of these courses: the high stakes of the examination for university entrance and the supposed impossibility of assessing modelling within timed examinations precluded this.

Especially prominent in the continuing argument for mathematics in the curriculum has been its central role as a tool or 'language', which opens the door to science. This argument has been advanced in the UK in the particular context of pre-university mathematics programmes as an argument for the teaching of Newtonian mechanics as a mathematical discipline, i.e., as an arena within which to develop skills of applied mathematics. However, the desire to encourage more students into mathematics education and the perceived difficulty of the physics concepts in mechanics led to a growth in the popularity of alternative applications, especially statistics. Attempts in the 1980s to make mechanics more engaging and attractive to students involved the development of practical and modelling projects and activities. These paralleled similar developments of the statistics curriculum projects of that era.

The central argument advanced was that an applied, problem-solving perspective motivates students to engage with mathematics. Thus, more students may be encouraged to study mathematics further, solving problems of shortages of mathematically equipped scientists and engineers for example. Two innovative schemes in the late 1980s developed courses and an examination scheme which incorporated modelling in its applied modules. Almost 40% of all pre-university students were following such reform schemes by mid 1990s, these two programmes are called Reform1 and Reform2 in this study. Finally in 1993 the government authority rewrote the national requirements for all such courses to include the examination of 'mathematical modelling' through some applied field such as mechanics or statistics (SCAA, 1993), and all examinations called mathematics were required to assess it. This is the historical background to this study of the effects of this national reform on the population of students and teachers involved.
Research on Attitudes and Modelling

While mathematics is about the study of patterns, the term mathematical modelling is synonymous in this paper with 'applied problem solving' and is defined as the process of applying mathematics to problems which arise outside mathematics itself. The principal aim for incorporating mathematical modelling activities into school mathematics programmes is to provide motivation for both teachers and students, and help the latter in developing problem solving skills (Blum and Niss, 1991; Kitchen and Williams, 1993; Niss, 1989; Swetz, 1991; Usiskin, 1989). This was particularly important in the 16-19 curriculum where most students drop mathematics in England and Wales. For this reason also modelling was at the heart of the free-standing Mathematics units developed for the UK Qualifications and Curriculum Authority for 16-19 year old students not following A’ level Mathematics (Wake, Williams & Jervis, 1999).

Small scale surveys of new mathematics reforms, such as Schools Mathematics Project 16-19 (SMP 16-19) and Mathematics in Education and Industries (MEI) incorporating and assessing modelling indicated increased accessibility and improved motivation to students in mathematics activities (Kitchen, 1993a). However, research evidence which examines teachers’ beliefs and practice of real life problem solving activities in comparison to more traditional ones and the effect of such work on pupils’ attitudes was very much lacking (Askew and Williams, 1995 p. 22).

The relation between beliefs, programme choice and assessment is complex. Teachers’ beliefs, which may have a significant influence on their choice of programme and materials they use, is known to be related to their practices (Ernest, 1989) especially in the implementation of new programmes. Furthermore teachers’ beliefs and practices do have significant influence on their students’ attitudes (Knapp and Peterson, 1995). Besides, assessment also exerts a pervasive influence on teachers’ practice which Burkhardt, et al. (1990) described as ‘what you test is what you get’.

Consequently, the objectives of this research were: (1) to evaluate and identify the major differences between the mathematical modelling elements of three programmes; (2) to investigate teachers’ beliefs about the importance of modelling and their practice of modelling in their programme.

The Three Implemented Mathematics Programmes Studied: Differences and Similarities

The three pre-university mathematics programmes for 16-19 year olds studied in this research were those of the School Mathematics Project 16-19 (ReformP1), Mathematics for Education and Industry (ReformP2) and University of London Examination and Assessment Council (TradP) respectively. Just as in other previous reform efforts, the two reform programmes were at the forefront in the development and assessment of students’ skills of mathematical modelling through written project work involving practical activities, real life problem solving and experiments throughout the 1980s. They developed networks of teachers working to improve their teaching of modelling and problem solving, developing practical activities and projects, and materials to support them.

The two reform programmes were also intended to be more accessible and motivating than the traditional ones they displaced (Dolan, 1990; Porkess, 1990). A significant component of their assessment is through project work, which is assessed by the teacher and fed back to the student as a profile of modelling and problem solving skills, such as
'communication', 'problem definition', 'model-building' and 'interpretation and validation'. This contrasts with TradP which assessed modelling only through some questions in the examinations, which goes some way towards acknowledging modelling as an activity without actually requiring any problem solving per se.

Table 1
Summary of Differences and Similarities with Respect to Mathematical Modelling and Applications in the Three Mathematics Programmes.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Aspects</th>
<th>ReformP1</th>
<th>ReformP2</th>
<th>TradP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course structure</td>
<td>Modelling in content aims.</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Modular?</td>
<td>No</td>
<td>Yes (6 Modules)</td>
<td>Yes (4 Modules)</td>
</tr>
<tr>
<td>Materials</td>
<td>Texts tailored?</td>
<td>Tailored and specified</td>
<td>Recommended</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Use of realism, experiments and practical work.</td>
<td>Yes</td>
<td>Yes</td>
<td>Not Necessary</td>
</tr>
<tr>
<td></td>
<td>Use of modelling processes/diagram.</td>
<td>Yes</td>
<td>Partial</td>
<td>No</td>
</tr>
<tr>
<td>Assessment</td>
<td>Coursework tests.</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Course projects.</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Modelling skills.</td>
<td>Assessed</td>
<td>Assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td></td>
<td>Final examinations.</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Teacher training</td>
<td>In-service training and support.</td>
<td>Extensive</td>
<td>Varied</td>
<td>little</td>
</tr>
</tbody>
</table>

Another significant dimension of difference between the programmes is their 'modularity'. ReformP2 and TradP are both fully modular, and often chosen by teachers because of this. Students may repeat the module tests until they succeed, and are never presented with a synoptic examination. But ReformP1 still demands an end of course examination, mainly of the pure mathematics. Other differences among the programmes can be seen in Table 1. Clearly there are many differences of detail, such as the training available, the hours of assessment in the course, and so on (Watson 1994, 1995).

Research Questions
It is expected that the different programmes would be associated with differences in teachers' attitudes to and experience of practicing mathematical modelling. As far as the teachers' attitudes are concerned, the goal is to know 'how important the teachers of mathematics believe mathematical modelling to be?', and especially 'how important do teachers of mathematics believe the assessment of modelling skills to be?' Most importantly, to what extent do the teachers' perceived importance of 'assessing modeling' is predicted by their understanding of the concept of modeling? It was further asked: Do teachers believe that they are able to practice modelling in their classrooms? and What do teachers believe mathematical modelling to mean?

Based on literature claims advanced about school mathematical modeling activities (Blum, 1993; Kitchen, 1993b), it was asked: Are teachers' attitudes to modelling influenced...
by (a) the programmes they are teaching, (b) their training experiences, and (c) their reported practice of modelling? However, a key to the investigation is the definition of teachers’ attitudes to modelling, and the instruments used to measure them.

The Research Instruments

Two instruments were used in collecting the data reported here. These are the teachers’ attitudes to modelling (TAM) questionnaire and a Teachers’ interview schedule. Items of the TAM questionnaire were constructed based on literature sources and interviews with teachers. Final TAM items were then validated through a factor analytic and construct framework using a sample of 96 teachers (pilot phase). The 5 factors of the TAM scale found in the study are reported in Table 2. The main data reported here was also used to confirm the factor structure and reliability of the TAM scales.

The TAM scale is designed to assess the level of teachers’ belief in the importance of the various aspects of mathematical modelling (with 28 items measured from unimportant (coded 1) to very important (coded 5)) and their reported frequency of classroom practice of these aspects (being a parallel set of 28 items measured from never (coded 1) to often (coded 4)) of mathematical modelling. A clearly distinctive five-factor structure was identified on TAM measuring teachers’ perceived importance and reported practice of (a) assessing understanding and skills of modelling; (b) real life applications of mathematics; (c) mathematical modelling processes; (d) communication skills in mathematics and (e) use of technology. The Cronbach (alpha) reliability coefficients for these TAM factors range from 0.77 to 0.87.

The identification of the TAM factors and their interpretation was supported by three other methodologies. First, a group of eight curriculum experts who have influenced the UK literature and curriculum were asked to provide descriptors for the sets of items collected into factors using factor analysis. For example, in factor two the words ‘real’ or ‘real world’ appeared together with the word ‘apply’ or ‘applications’ in six of the experts’ definitions. Factor five was unanimously termed ‘use of technology’. Thus the final names for the factors were consistent with the majority of the ‘experts’ nominations. Second, the teachers were asked to describe what they thought modelling was, and their open responses were categorised as reflecting the factor-definitions if they used concepts which were similar or synonymous (the researcher and an educational linguist independently established these with an inter-rater reliability of over 80%). Lastly, the factors were scaled using item response theory that confirmed the factors as been robust. Further details about the development, validity and reliability analyses of the instrument may be found elsewhere (Kyeleve & Williams, 1996; Kyeleve & Williams, 2006).

Detailed written descriptions of all observed classrooms modelling activities, mainly of a practical and experimental nature, were done with no pre-coded format due to the varying nature of such classroom sessions. Interviews and observations were designed to seek clarifications and explanations for the emerging patterns of teachers’ beliefs, their reported practice and of students’ attitudes to mathematical modelling in the classroom context.

The Research Design, Procedure and Data Collection

This research was conducted in two phases. The pilot phase focused on constructing and validating the TAM instruments using 96 teachers from six 16-19 mathematics programmes
including the three studied in the main phase. The sample consisted of fifteen schools and colleges in England from which subjects were drawn. Among the fifteen selected schools, five each offered one of the three mathematics programmes studied. Six members of the University research team participated and assisted in the selection of ‘comparable’ groups of schools using their knowledge of the nature, location and other educational characteristics of these institutions, based on information collected from schools annually over several years. “Comparable” is defined here to mean similarity in terms of students’ population, the number of mathematics teachers and students’ composition (mixed or single-sex) and location. Each set of 3 comparable schools using one of the three programmes studied respectively was selected among High schools (for 11-18 year olds), Sixth form colleges, Further Education College, and Independent schools across the UK.

The TAM scale were administered to the teachers (N = 37) through the head of mathematics department in each of the fifteen selected schools in the main study. There were also several classroom observations of modelling activities in three sampled schools lasting one to two hours each. The interviews with teachers were carried out after analysis of the teachers’ attitudinal data generated using the TAM scale.

Design of Analyses
The scale factors provided the unit of analysis designated as F1 to F5 and P1 to P5 for the teachers’ beliefs and reported practice of modelling respectively. Factor mean scores (µ) and standard deviations (µ) represented repeated measures on each sub-scale. The factors’ mean scores (µf) range from 1 to 5 except for P1 to P5 (µp) which range from 1 to 4 based on the 4 options provided and their coding format (see description of research instrument above).

The single-factor, repeated measures design (Winer, 1971) was used to explore differences in the level of teachers’ beliefs about the teachers’ perceived importance and reported practice of mathematical modelling among the identified five factors. Multiple regression analysis was used to investigate the extent to which: (a) the teachers’ belief about the importance of assessment predicts their conceptual belief about the importance of the other four factors in modelling and (b) teachers’ beliefs explains their reported practice. Both the pilot and main data are reported to discern trend and consistency (if any). The population (d) effect size was used to identify any educational significance to the statistical results (Fitz-Gibbon, 1984; Hedges & Olkin, 1984; Tamir, 1991). All the effect sizes were corrected using the factors’ Cronbach (alpha) reliability coefficients.

The statistical analyses (using the SPSS) are based on the cross-sectional quasi-experimental design in a natural setting, because of the selection of the three mathematics programmes by the teachers in schools themselves, rather than by the researchers. Interview and classroom observation data provided explanatory data, complementary to the statistical results found in the teachers’ beliefs and practices of modelling among the mathematics programmes.

Results

Teachers’ Beliefs and Reported Practice of Mathematical Modelling.
We found significant differences in the mean scores among the factors on the TAM (F-value (df =4) = 2.53* for beliefs and F-value (df =4) = 4.55* for practice, *P<0.05). Tukey’s HSD test indicated differences between F1 and the other four F-factors and P1 with the other P-factors. These results were consistent with those of the pilot data with respect to teachers from the three programmes (see Table 2 for mean score). So, teachers’ belief about the
importance and practice of ‘assessing understanding and skills of mathematical modelling’ is higher than their belief and reported practice of all the other four factors of (a) teaching mathematical modelling processes, (b) communication skills, (c) using real life situations and (d) using technology in mathematics. This is interpreted to mean that teachers expressed stronger views about the importance of assessment than about the other factors of modelling.

Table 2
The Relationship between Teachers’ Beliefs and Reported Practice of modeling, Effect Size, Factor Mean Scores and Standard Deviation; Pilot (N=96), Main (N=37).

<table>
<thead>
<tr>
<th>Teacher Belief</th>
<th>Teacher Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1/P1</td>
<td>.24</td>
</tr>
<tr>
<td>F2/P2</td>
<td>.45*</td>
</tr>
<tr>
<td>F3/P3</td>
<td>.40*</td>
</tr>
<tr>
<td>F4/P4</td>
<td>.44*</td>
</tr>
<tr>
<td>F5/P5</td>
<td>.46*</td>
</tr>
</tbody>
</table>

*p < 0.01 (2-tailed); F1/P1 = Assessing understanding and skills of mathematical modelling; F2/P2 = Real life applications of maths; F3/P3 = Communication skills in maths; F4/P4 = Teaching & learning mathematical modelling processes; F5/P5 = Use of technology; ESP = Effect Size for Pilot; ESM = Effect Size for Main; MSDP = Mean±SD for Pilot; MSDM = Mean±SD for Main.

Next, the extent to which the teachers’ perceived importance of assessment is predicted by their beliefs about the importance of the other factors of modelling was examined (see third research question). The factor concerned with the importance of assessing understanding and skills of modelling (F1) was regressed, as the dependent variable, on the other four factors (F2 to F5). The three factors of real life applications of mathematics (F2), mathematical modelling processes (F4) and communication skills in mathematics (F3) significantly explained 42% of the variation in F1 (F1 = .2F2 + .16F3 + .26F4 + .28).

This result is consistent with the teachers’ statements defining their concept of mathematical modelling provided by fifty of the teachers (pilot data) on an open-ended question. The teachers’ concept of modelling was largely described in terms consistent with F2, F3 or F4. For example, two of the teachers’ definitions were:

T1. Modelling is/should be the process where students (1) set up a model of a situation and consider the variables/limitations involved; (2) test a given law and gain evidence to support it rather than just accept it. (reflect F2 and F4).

T2. Modelling is translating a real life situation into mathematical concepts and quantities with the aid of various assumptions in order to predict or explain the outcome. (reflecting F2, F3 and F4).

Thus, 72% of the definitions were categorised as referring at least partially to F2, 76% to F3 and 40% to F4. Only three definitions reflected use of technology or assessment issues, which are more relevant to pedagogical implementation than to the concept of modelling.

Using the same regression techniques, the scope of reported practice of each factor was regressed as the dependent factor on the corresponding teachers’ belief factor. The result indicated that teachers’ beliefs about the importance of the factors of mathematical
modelling accounts for about 16-21% of their reported practice of the corresponding factors of modelling in the mathematics programmes. Table 2 also shows the relationship between the teachers’ beliefs and their reported practice (column 1 & 2), and the effect of the former on the latter (column 3 & 4), of teaching mathematical modelling. The relationship is significant on all factors except for ‘assessing understanding and skills of mathematical modelling’ (pilot data). This was surely due to the larger number of teachers in the pilot data whose programmes had not yet incorporated assessment of mathematical modelling into their examination programme.

Training and Programme Effects on Teachers’ Attitudes and Practice of Modelling.
The main and interacting effects of In-service training participation (INSET), nested in programme was examined using a two by three by five factorial design- repeated measures; that is, INSET (two levels) by Programme (three levels) by Modelling factors (five levels). The results of ANOVA (repeated measures design) indicated no significant interaction effects of INSET and programme variables on the level of teachers’ beliefs (F-value df=8 = .40) nor practice (F-value df=48= 0.81) across the modelling factors. The INSET variable had no significant main effect on both the level of teachers’ beliefs (F-value df =4 = 1.26) and reported practice (F-value df=4 = 0.74) across the modelling factors. Programme variable was found to have a significant main effect on the level of teachers’ reported practice (F-value df =8 = 2.25*, *p < 0.05) but not on their beliefs (F-value df=8 = 1.17) across modelling factors. Thus, it seems that for teachers, the issue of modelling and problem solving is expressed as one of curriculum implementation and not one of beliefs as a matter of principle.

Table 3
The Effect Sizes of the Teachers’ Reported Practice of Mathematical Modelling Among the Three Programmes.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Effect Sizes Between</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TPvsRP1</td>
</tr>
<tr>
<td>Assessing understanding and skills of</td>
<td>1.11</td>
</tr>
<tr>
<td>mathematical modelling</td>
<td></td>
</tr>
<tr>
<td>Real life applications of mathematics</td>
<td>0.37</td>
</tr>
<tr>
<td>Communication skills in mathematics.</td>
<td>1.02</td>
</tr>
<tr>
<td>Teaching mathematical modelling processes</td>
<td>1.52</td>
</tr>
<tr>
<td>Use of technology.</td>
<td>0.56</td>
</tr>
</tbody>
</table>

TP = TradP; RP1 = ReformP1; RP2 = ReformP2

Using the Univariate F-test, the effect of programme on the level of teachers’ practice was found to be significant on the factors of ‘assessing understanding and skills of modelling’ and ‘teaching mathematical modelling processes’. The effect sizes of the teachers’ practice of modelling among the three programmes illustrate the magnitude of these differences (see table 3). A positive effect size is in favour of the second programme taken as the experimental group and a negative effect size is in favour of the first programme taken as the control group. Only scores of the INSET groups (teachers with in-service support experience) were used since the non-INSET teachers using the TradP were believed to over rate their scores. None of the non-INSET TradP teachers provided a definition of mathematical modelling and we came to the conclusion that they had a different understanding of what mathematical modelling means.
Clearly, trained teachers using the two reform programmes reported a higher scope of practice than those using the traditional programme did. The large effect sizes between teachers using the ReformP2 and ReformP1 on their practice of communication skills and the teaching of mathematical modelling processes may be due to the extensive teacher support and available text materials for teaching modelling activities favouring the latter. In general, most teachers felt it is important for students to learn the identified skills (factors) of mathematical modelling. However, those using the traditional programme, which has the minimum assessment requirement in modelling, were sceptical of practising the assessment factor (P1) as illustrated by the typical comments made in interview by one teacher:

I: In your own opinion, would you consider mathematical modelling to be an important aspect to be learnt by students and assessed?

2TD: I think they will need it in mathematics, it is the question of the proportion. I think they need the practical experience but it doesn’t have to be examined.

All the three teachers interviewed using the traditional programme expressed the same view supporting their low level of reported practice of assessing students’ skills of modelling. This seemed to be the main programme difference between the teachers’ attitudes. It is interesting however that training was not a main effect. Clearly in this context the significant impact arises from the interaction of training and programme implemented. Although this was not anticipated, it is perfectly reasonable.

*Teachers’ Awareness, Beliefs and Choice of Mathematics Programmes.*

Theoretically, the compulsory aspects of mathematical modelling are met in five units of the ReformP1 and in two units of the ReformP2 and TradP programmes. Mathematical modelling has been largely avoided in the traditional programme, which has merely included the objectives of modelling without specifying a content domain in any of its modules, and which has no modelling project work.

With a long standing culture of providing choice from several differing programmes of various examination boards and independent curriculum projects that are approved by SCAA, school mathematics departments select and recommend the mathematics programme(s) they may elect to follow to their boards. However, the final consideration and approval usually rests with the school boards. Interview evidence indicates that teachers are aware of the differences between the new and the more traditional mathematics programmes with respect to practical activities, coursework demands and written project work in modelling. In interviews, teachers gave 4 main influences on their decision to change to a selected reform programmes: the programmes’ accessibility, the transition for students from their previous pre-I6 mathematics course into the programme, the incorporation of varied teaching styles and finally the assessment modes. As one teacher said:

2TA: I think the main reason why, was that with the growing awareness of the fact that with the GCSE, we were not building on the strength of that course. All we were seeing at this level (pre University) was the negative aspects. One, we didn’t achieve much for the majority of students at this level as we use to do at the ‘O’ level. A lot of the pupils were beginning to switch off because they would start ‘A’ level mathematics programmes and went straight to do complex algebraic manipulations. They found that difficult. I also felt over the years, there were pupils who were getting grades lower than they should have got for their ability. So when the ... ReformP1... mathematics programme came up, we immediately
went for it. I was impressed with the way it was built on the pre-16 maths programme. I felt it was a natural follow up to build on that strength: the coursework coming in, the investigation element coming in and the algebra built up was steadier than had been before. So I felt very much this was the programme to follow. And suddenly, the students’ results reflected what in my opinion they ought to have been and I have been very pleased with the programme.

Other teachers interviewed using ReformP1 echoed similar reasons with respect to inaccessibility of the more traditional mathematics programmes and the need for continuity of learning experiences developed previously. The teachers also believed that the reform programmes might be more motivating to students as demonstrated elsewhere (Kyeleve, 2004). In addition to the above reasons, teachers using the ReformP2 cited the modular nature of their programme, which provides more flexibility. In contrast, teachers using TradP, including the two quoted (TH and TG), were apprehensive of the new trends, especially the assessment of modelling skills.

1TH: What is on the new course is going to cause problems to some of the programmes we traditionally follow with our students. But as we see it at the moment, the programme (TRADP) we use is trying to find a way around it.

1TG: As far as practical work is concerned, I am not for a mixture of it at the moment, to be honest. We have actually deliberated on the system that’s why we choose to do this one (TradP) rather than the others. One of the things that encouraged us in that direction was the coursework in statistics. I think, it is fair to say that we wouldn’t want to see too much practical work examined in mechanics. One of the things that will concern us about that is that you would be spending much time on practical work. We did look at other possible programmes that involved practical work like the SMP 16-19 and we felt they were pretty more practical work there than could be…. we felt, we could justify.

Unlike the two reform programmes which teachers confirmed in interview were more accessible, the traditional programme was clearly perceived to be less accessible to students. Teachers using the TradP indicated addressing this problem of inaccessibility by organising extra support lessons (a typical traditional remedial methodology), by selecting only able students or occasionally by adopting other programmes believed to be more accessible to less able students.

**Conclusion and Discussion**

The data and results of analyses presented in this article indicate that teachers’ perceived importance of mathematical modelling in pre University mathematics programmes is defined by five factors (here in order of their perceived level of importance): assessing understanding and skills of mathematical modelling, strategies for teaching modelling processes, real life applications, communication skills and use of technology. But, whereas the differences among the programmes were small for the teachers' attitudes (except the importance of assessing modelling skills), the corresponding effects of the different programmes on students’ attitudes were great (Kyeleve, 2004). It is possible to account for this difference in several ways. It may be that the way teachers respond to the questionnaire is affected by what they think one wants to hear, or what the official story is (much as
Stigler's teachers may have said they thought they were implementing the National reform. It may be that the programme they have chosen to teach shaped their understanding of what 'modelling' means. Thus, the teachers might have quite different attitudes to modelling even though their responses to the questionnaire were similar. In other words, one possibility is that the validity of the TAM may be deficient, but that was not the case (see Kyeleve & Williams, 2006).

Further more, in discussions with teachers in the development and validation of the questionnaire did not show this was the case. Teachers who chose the traditional programme did so because they thought that the ideas of the reform were fine 'in principle', but not in their classes for their students, for various reasons including lack of time. Indeed, the developers of the programme shaped it so as to place it this way, literally in the marketplace of programmes.

The most favoured interpretation then is that the programme, its materials and assessment did indeed affect the students’ attitudes as it were 'directly', by allowing the modelling reform to take concrete shape in the daily life culture of the classroom, even though the programme did not have a significant effect on the teachers’ attitudes. It is not claimed that the programme had such an effect completely 'independent of the teacher', however. What was seen was the major effect sizes in the reform programmes effect on teachers’ frequency of practice, which is facilitated by the different programmes in different ways. So the correct interpretation is that the reform programmes allowed teachers positive attitude to modelling to play its intended pedagogical role in the classroom culture. Thus this national reform, described technically accurately as 'from the top', became effective because there was a professional culture to some extent prepared to receive and celebrate it. Some of the strongest effects of the reform (i.e. ReformP1) emerged in the programmes whose modelling practices had developed before the reform, in which teachers had participated in writing materials and training their colleagues in the new programme, as one would expect. In effect one might claim that the reform worked best where practices consistent with the reform had previously been developed, i.e. where the reform was least 'top-down'.

The very small number of less able students (with C grade and below) taking the TradP illustrates the relative inaccessibility of the more traditional programmes as compared to reform programmes incorporating coursework in mathematical modelling through project activities. Though the more traditional programmes are not assessing much of the modelling skills by written project work, teachers using such programmes who believe it is important to teach some aspect of modelling are likely to include it in their own practices to some extent. But without assessment, such teachers seem at best claim to develop only some ‘intuitive feel’ for modelling in their students. It is, therefore, not surprising that of the background variables studied, assessment was the source of the most significant differences in teachers beliefs and practice (Burghes, 1989; Burkhardt et al., 1990).

In summary, reliable and valid scales can be developed to evaluate the main aim of a curriculum reform intended to improve teachers’ attitudes, in this case to mathematical modelling. The scale was used to explore the effects of three different implementations of the reform, against background variables such as training received and so on. Differences were usually consistent with what previous literature on attitudes and common sense would suggest, at least in terms of direction. Some challenging and some encouraging but surprising findings were reported. Difficulties in the separation of the statistical effects of different aspects of the implementations were manifested. Accordingly these are embraced...
within an interpretative methodology by appealing to the complexity of the history and social situation in which the three programmes were developed.

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