Developing Double Major Programmes with Math as one: Challenge and Response

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Abstract

In the past, demands from the market, new opportunity areas, and national strategies were important drivers to developing new academic programmes. With quality gaining acceptance and importance in the Higher education sector, academic programmes are developed to meet the requirements of *National Qualification framework* or such other prescriptions as may exist. Furthermore, institutions look forward to benchmarking their programmes. All these have made curriculum development more interesting and challenging.

In the context of modules and programmes that involve Math, curriculum development is exciting as different specialisations weave around various subject areas in Math. Recent developments in the computer industry have made it attractive to graduates with Mathematics major. While the rigorous training in Mathematics places them on a good footing, the need of the industry will be better served if these graduates have a stronger background in the actual application that they are required to work on. A double major degree programme will cater to the interests of the students as well as the needs of the industry. The second major in such scenarios can be Image Processing, Artificial Intelligence, Cryptography, Computer Graphics, and so on.

The curriculum structure needs to take into account the core modules mandatory for all the students of the institution, the support modules from other subject areas, modules for a major in Mathematics, and modules from the other major apart from optional modules. Moreover, exit at different points as well as associated skills and knowledge must be considered. All these add to the care and expertise with which the curriculum needs to be developed.

For the purpose of developing such a double major programme, a central repository of subjects will be useful. This repository, with modules at various levels with different learning outcomes, will serve as a resource to developing several programmes with different specialisations. While the ownership of different modules within the repository will lie with the respective departments, the common qualification framework will be the basis to bring about the overall balance in the curriculum structure. In this paper we discuss the challenge of developing such a curriculum and our response to it.

1. Introduction

With the increase in the types of academic models and availability of information at the click of a button, key stake holders in the educational sectors have realised the need to develop appropriate quality assurance mechanisms in different areas relating to the academic sector in order to ensure that the students get quality education across institutions. The increasing number of quality networks, quality assurance agencies and accreditation bodies in different countries and regions are examples of this effort.

In the past, key factors considered for curriculum development included market demands, national or regional strategies, and new opportunity areas. However in the present day context, curriculum developers have to consider several factors such as appropriateness of the academic structure, financial viability of the programme, employment opportunities and social relevance in addition to benchmarking, uniqueness of the programme and alignment with national qualification framework or prescriptions from accreditation bodies and other agencies.

Interestingly, Math is a multidisciplinary subject enriched by an array of practitioners with empirical and theoretical developments. In the past, most of these studies were considered in isolation and drawn into the curriculum as need-based courses or optional subjects.

Growing challenges and opportunities coupled with attractive compensations have drawn several students with Mathematics major into the IT industry and allied sectors, engaged in a variety of projects that involve application of mathematical tools and techniques. Several universities made changes to their programmes that included Math as an integral component. However, in most situations, these were a part of programmes relating to IT or computing. Common approaches in all these initiatives were to strengthen the Math component or focus on programmes with a Math orientation.

In [1], Bruce underlines the need for including elements that promote Mathematics as well as mathematical thinking in computer science education in order to equip students to respond to all stages of system development. Key factors in the design and implementation of an Information Technology Major and the limitations in developing a new programme in a resource constrained environment have been studied by Sobiesk et al. in [2].

Challenges faced by small colleges working with limited resources in responding to recommendations to curriculum changes in Mathematics and the consequential effect on other courses have been outlined in [3]. Blahnik et al. describe how modifications were made to a computer science major to include concentrations in other subject areas such as Business information systems and graphic design and implementation in partnership with other disciplines in [4].

Taking a critical view of the content of Math in undergraduate computer science education Kelemen et al. emphasises the need to integrate mathematical maturity

throughout the study of computer science in [5]. The influence of a separate discipline IT in the traditional computer science programme has been reported in [6].

A one-year, two-course model that relies on collaborative effort of computer science faculty and the faculty of mathematics with the initial course taught by the former and the second course taught by the latter has been developed in [7]. The importance of including computational issues through the study of computational discrete mathematics in a computer science major has been discussed in [8]. The intimate relationship between computer science and new areas of applicable mathematics has been explored in [9].

In all these initiatives, the importance of including Math components at varying levels has been considered. Yet, these initiatives have not provided substantial gains to enrich the curriculum with the required mathematical rigour, logical ability and analytical thinking. Still there are gaps. As a consequence, companies incur substantial training costs resulting in late start to be on the job. In some situations, students are caught between the demands of the work place and new knowledge areas, and this leads to an increase in their frustration levels.

All these call for developing programmes that will enhance the learning experience by introducing an integrated method that will blend the skills and knowledge realised in Math as well as another relevant specialisation.

Some universities made a brave beginning by introducing a double major system that allows students to specialize in two different subject areas. Universities that offer programmes leading to specialisation in two majors use different measures to check whether the student qualifies for the award. Also, universities adopt different nomenclature to specify the subjects considered as the first and second major. In all these discussions universities distinguish a double degree from double major.

Our approach to including Math stems from the fact that its role and scope are increasing in several application domains calling for graduates with expertise in Math as well as in a related application area. Hence there is a need to develop programmes which facilitate specialisation in two different subject areas one of which is Math.

The remaining parts of the paper address issues relating to creating such a curriculum. In section 2 the objectives and rationale of the curriculum is discussed. Section 3 outlines the significant features of the curriculum. Section 4 provides an overview of the curriculum and describes the modules such as the core modules, specialisation modules, computing skills, English language component, general education component, optional and details of project.

Section 5 discusses the details of different exit awards including interim exit awards and the credit points required for this purpose. In Section 6 the programme is discussed from different perspectives and in Section 7 limitations of the programme and possible areas for further studies are reported. Important conclusions are given in section 8.

2. Curricular Objectives and rationale

In all our discussions, our basic premise is that a curriculum that ties together skills and knowledge in Math with another subject area will prove useful to the student considering a variety of applications that are growing in the two areas. These programmes will enhance the mathematical skills of students and give them a unique opportunity to prepare for a career in many related fields. In all these efforts we remind ourselves that the programme is a four year Bachelors programme.

The curriculum design has several key objectives that are important to providing breadth and understanding of Math and related discipline as well as develop the ability to synthesize various skills systematically. In particular, the following are specific goals of the curriculum design:

- The curriculum should necessitate students to take charge of the learning process
- Substantial contribution to knowledge building should emerge from students' contribution in a variety of ways
- The curriculum should provide the required foundation for life long learning
- Students should be exposed to different scenarios wherein one or more of the skills learnt can be applied
- A fine blend of theory and practice with well defined learning outcomes should be reflected in the curriculum
- Promote students to work as a part of a team and as individuals
- Emphasise the need to appreciate a value system in their life and work
- Scope in elements of communication in a variety of ways
- Develop entrepreneurial skills or enhance professional status according to student's interest
- Provide opportunities to understand the national/regional/international culture, common practices and make them familiar with global demands and developments
- Equip the students to go beyond responding; to identifying issues and finding ways of providing solutions to them

3. Significant features of the curriculum

As the programme is a double major programme and that several programmes with Math as one of the major will be offered by the institution, all the programmes proposed are based on larger institutional goals (usually following a *national framework* or other prescriptions) rather than specific activities closely related to individual programmes. Thus the curriculum has the following features:

1. It provides *flexibility*. Students have opportunities to make their own path of progression through the curriculum and can take recourse to their major (other than Math). For instance a student can move from Artificial Intelligence to Computer Security as the second major provided certain conditions are satisfied.

Usually when such movements occur at early stages of study not much time is lost.

2. Modules support to progressively *develop intellectual capabilities* and add to the body of knowledge rather than to module count. For instance the curriculum will not focus on a variety of front end tools but will provide the necessary skills in the front end technology.

3. Students must find opportunities to build a positive relationship with the community; understand the needs of the society and support the needy. Such a philosophy is common in several academic curricula. The curriculum supports *overall development* of the students and prepares them to be useful citizen. Students are encouraged to understand and promote social, cultural, literary and other forms of activities based on their interest which directly or otherwise promote their extracurricular interests and develop their interpersonal and communication skills.

4. There have been attempts in the past to include the *general education* component as a part of the curricula. Every student needs to have some basic knowledge in areas outside the domain of the two majors that are likely to be useful for the day to day life.

5. Between application and theory, the curriculum emphasises *application of techniques*. For instance, the curriculum will not focus on the theory behind the development of different numerical solutions but will require the student to identify an appropriate technique and apply the same to a variety of problems.

6. Curriculum provides opportunities for students to opt for a *professional practice mode or an entrepreneurial mode*. Students keen on setting up their own business will need skills and knowledge required to become successful entrepreneurs. They need to be familiar with general business practices and need to experience such skills during the study. On the other hand students intending to go for employment need to enhance their professional capabilities and be best suited for a work environment.

4. An overview of the curriculum

The first step to developing the curriculum is to identify a *frame* that provides the broad subject area along with possible specialisations. Figures 1 and 2 provide a *frame* with a. Math and Computer Science and b. Math and Business Studies. It is important to identify specialisations from amongst those that are listed. For instance *frame* 1 provides different specialisations in Computer Science such as Software Engineering and Computer Graphics. Similarly *frame* 2 provides a possible list of specialisations from Business studies.

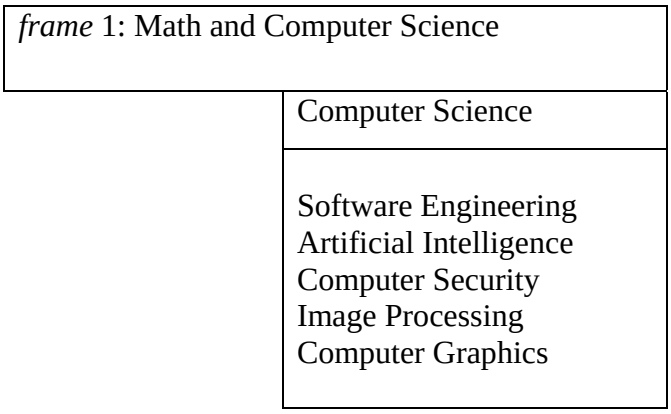

Figure 1 *frame* 1: Math and Computer Science

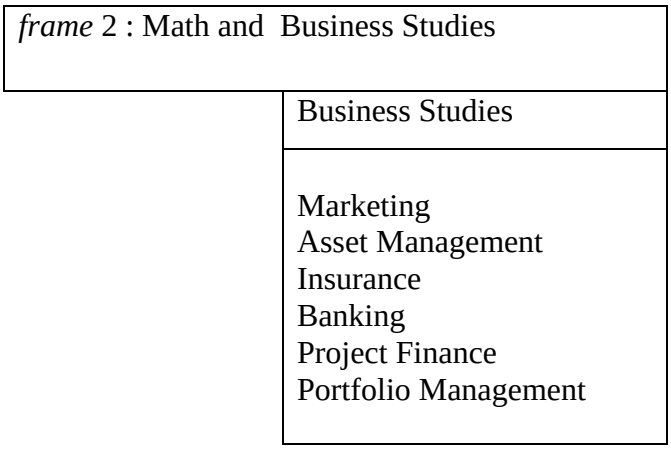

Figure 2 *frame* 2: Math and Business Studies

In effect the programme leads to awards with Math as one major and another from the chosen specialisations listed in one of the frames. Thus the programme is designed for an award, in two majors, say, Math and Software Engineering or Math and Artificial Intelligence or Math and Computer Security etc.

In terms of modules, all the programmes that are identified under the framework of the broad subject area say Math and Computer Science will have certain *core Math* and *core Computer Science* modules that are common to all specialisations identified under this framework. In addition to these core modules, certain Math modules and modules from Computer Science that are specific to the specialisation under the framework are also included. These modules are referred to as *Specialisation Math* and *Specialisation Computer Science* modules. Care is taken to include a module that serves as an introduction to the specialisation under the *Specialisation* module list.

In addition, a set of modules that are important to developing *key computing skills* and those from *general education* are also included. *English for Special purposes* module is included to develop the students' skills with a focus on the broad field of study. Students who study with Math and a specialisation from Computing will have a different focus from those who study, for instance, Math and a specialisation from Business Studies or Biology.

Students are provided with opportunities to understand real time environment in teams and as individuals depending on the nature of projects and the levels. In a mini project students are usually expected to work in teams. Students graduating would have experienced a dedicated one semester period to enhance professional skills or entrepreneurial skills in a real time environment. This is followed by developing a product or project proposal in the final semester of study. Students could choose a set of *optional modules* from different departments.

Thus, in the case of *frame* 1, with Math and a specialisation from Computer Science as double major, the programme is structured to include a. Core Math module and Core Computer Science module b. Specialisation Math and specialisation Computer Science modules c. modules relating to computing skills d. English for special purposes e. General education f. Optional modules and g. project at different levels. All these are described in Figure 3.

A. Core modules

Most of the traditional programmes with Math as a single major include fundamental modules such as Algebra, two and three dimensional Analytical Geometry, Vector Algebra, Calculus, and also advanced modules such as Real Analysis, Complex Analysis, Vector Algebra, Dynamics and Statics, Mechanics, Astronomy, Special Functions etc.

The purpose of developing a double major is not to include all modules usually found in Math major as well as the other major. Such an arrangement will only necessitate adding more modules to the programme even after carefully deleting duplication. Moreover one of the aims of double major system is to equip the learner with the rigour and skills required by including the necessary components of the specialisation subject in the chosen *frame* as well as the related mathematical elements.

In the case of *frame* 1, from a careful analysis of subjects included for specialisation we find the need to include the following modules as Core Math modules: 1. Calculus 2. Logic and Abstraction 3. Numerical Methods 4. Discrete mathematics 5. Graph Theory and 6. Combinatorics. It is important to note that a conscious decision is made not to include modules that are usually included in a conventional curriculum with Math as a major as they do not significantly contribute to the double major programme with any of the specialisations from Computer Science considered in this development process.

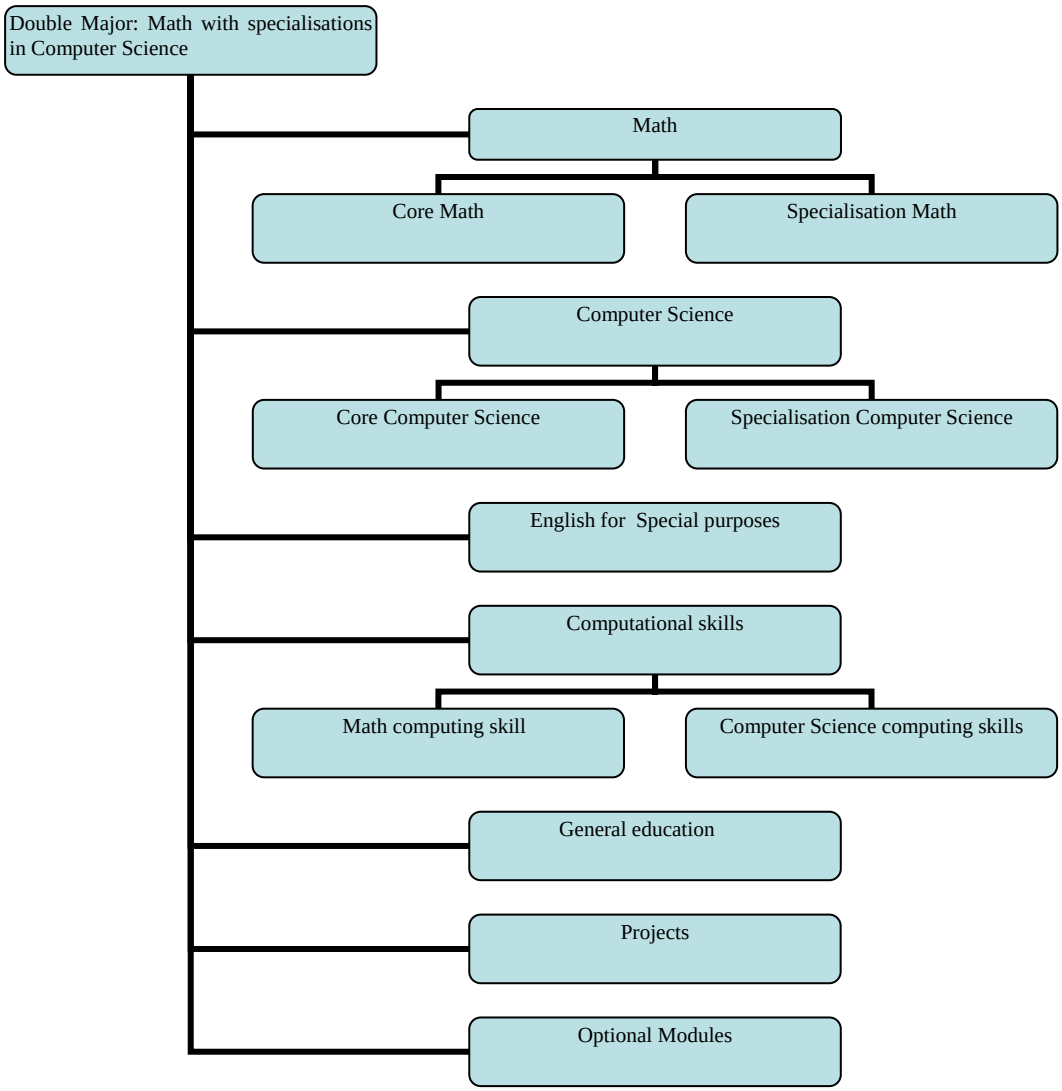

Figure 3 A Structure for Math with Specialisations in Computer Science

Similarly, the modules that are usually included in a typical computer science curriculum are also deliberately not included as the core Computer science modules. Thus in the curriculum with *frame* 1 as the base, only modules that have meaningful relationships to the broad subject area viz. computer science have been considered. The following core Computer Science modules have been included: 1. Data Structures and Algorithms 2. Database management systems 3. Computer Architecture 4. Hardware and networking 5. Systems Software, and 6. Operating Systems

The purpose of including a set of core modules from both Math as well as the broad field is the following:

- To provide the necessary solid fundamentals to motivate students in both the subject areas
- To provide the necessary key skills, knowledge in the broad field of study as well as Math.

- To provide opportunities to appreciate the relationship between Math as well the chosen specialisation
- To explore a variety of problems in the chosen specialisation; understand their complexity and identify ways of solving them with the aid of familiar tools and knowledge built in other subject areas.

It must be emphasised that in most of the situations practical components are included, particularly in the initial stages of learning and less emphasis is placed on items such as derivations and proofs, memorization of lengthy formulas though students will be required to identify the relevant formula that needs to be used for a given problem.

B. Specialisation modules

For the purpose of meeting the desired learning outcomes of the programmes, certain modules from Math are required to be included in addition to modules relating to specialisation. For instance the following modules are required for a specialisation in Software Engineering (from the broad field of Computer Science): 1. Introduction to Software Engineering 2. CASE tool concepts, and 3. Software project management. Modules required from Math in order to support this specialisation include the following: 1. Mathematical Statistics 2. Formal languages and Automata, and 3.Econometrics.

Specialisation modules provide the necessary exposure to identify suitable problems for further investigations and are best suited for projects and during industrial internships. These modules serve as aid to understand current trends in the field and provide valuable clues to determining subject areas for further studies or opportunities for employment. Possible choices of specialisation in Math modules as well as the other major are given in Figure 4.

C. Computing skills

With the growth in technology, supported by software and other tools, options are available to perform computing at the desired skill level. It is important that students have knowledge about such tools and possess the required skills in using such toolsets. In the context of a double major with Math as one, there are several mathematical software packages that could be used in a variety of applications.

A typical set of software that could be used for *frame* 1 will include the following 1. MS Office 2. MatLab, and 3. C++/Java. This set would serve the general purpose of all specialisations in *frame* 1. However, for *frame* 2 a more meaningful composition will include software such as MS Office, OpSearch, and SPSS. Thus the nature of skills that are likely to be acquired from this component in the programme will depend on the *frame* and not on the specialisations.

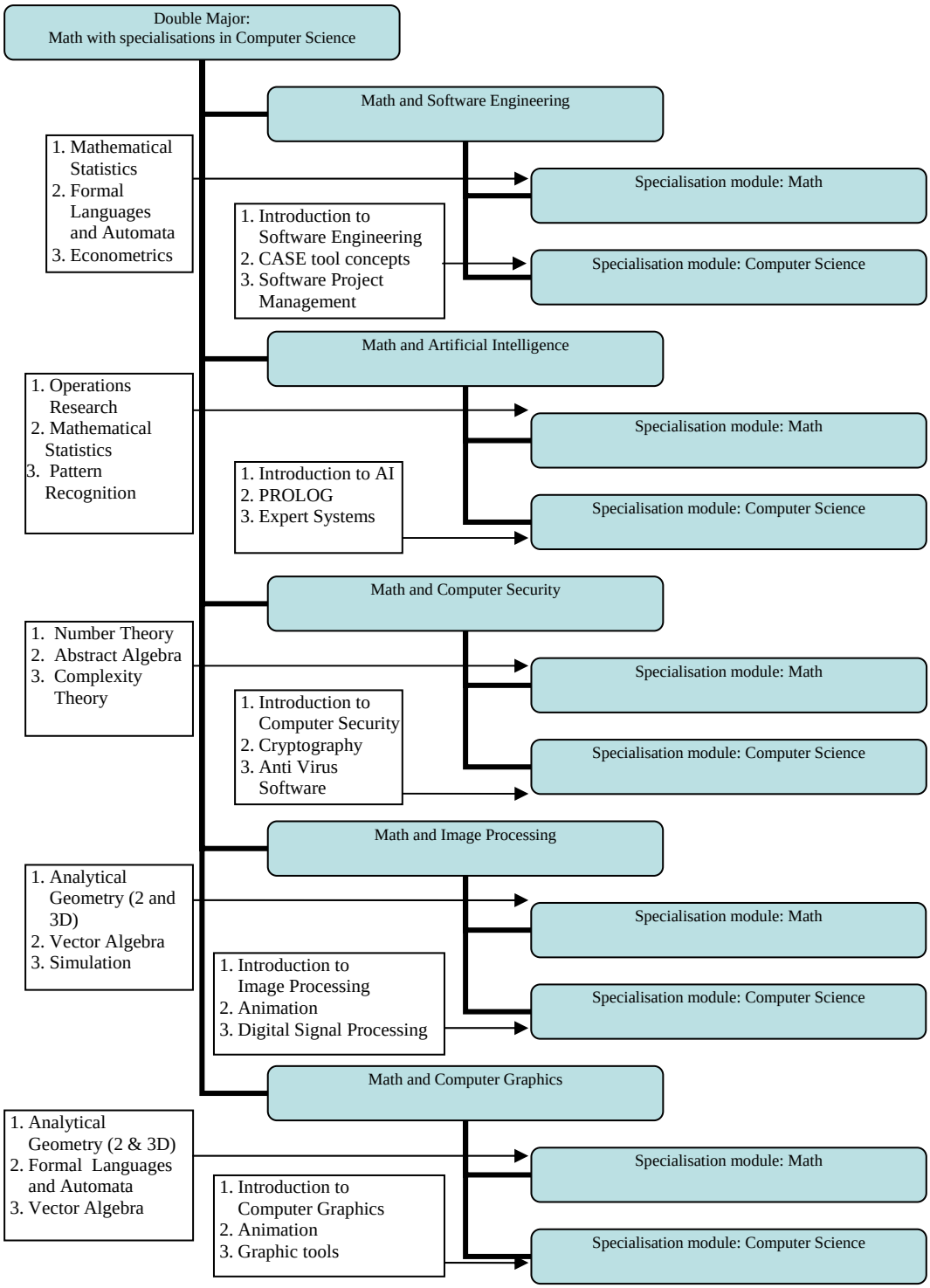

Figure 4 List of specialisation modules for double major:
Math and specialisation in Computer Science

D. English for special purposes

In order to communicate ideas effectively and to make the learning process successful, it is important that students build their English language skills. This curriculum emphasises the use of English language as an effective tool set in a variety of ways. Thus the curriculum is specific to the broad field of study.

In other words, the curriculum for this component depends on the *frame*. The curriculum for the *frame Math and Computer Science* will be different from the curriculum for the *frame Math and Biology* though there may be some common goals.

It must be mentioned that students taking this module will have already sufficient knowledge and skills in English language reflected through reading, writing, listening and speaking skills.

E. General education

Many universities have underscored the need to include a general education component in their curricula. Experiences of students, advising staff and, faculty in implementing a general education component have been reported in [10]. What constitutes a general education differs from one institution to the other. The general education component, we believe, largely stems from factors such as the national priorities, local needs, building a value system, preserving the rich culture and heritage of the country. The components included should enable the student to respect, build and promote a value system based on moral values.

General education should serve as a window to the world moving beyond the local, regional to the international domain, all through the path realising the need for building a peaceful world, with mutual support, respecting each other and sustained progression. This should also build students' leadership quality, team building skills, and understand fossilisation across cultures.

F. Optional modules

In order to facilitate students to choose modules that may be appropriate to their project or during their internship, optional modules are included in the curriculum. Students may choose these modules on account of their personal interest as well. These modules will be offered by different departments and in some cases augment the body of knowledge in specified domains.

G. Project

Importance of teaching entrepreneurship has been dealt in detail by several authors. A review of entrepreneurship, debates over teaching entrepreneurship etc are studied in [11]. At the centre of the curriculum is an ambitious entrepreneurship/professional development component extending over one whole semester. Students could choose to

become a successful entrepreneur by focusing on related skills or become suitable for employment by enhancing their professional expertise. The path to this begins with a mini project for the award of Diploma (in the fourth semester); an internship in an industrial environment for a one semester period in the seventh semester with a learning outcome that develops as a project initiative in the eighth semester. Thus the student is exposed to real time environment at three time points with varying degrees of involvement.

The mini project is basically a team project. An issue that is identified is studied in detail, with support from peers guided by an adviser. In this type of projects student will have a thorough understanding of issues and in most cases provide solution using known techniques. The project at this stage aims to promote team building, enhance communication skills and develop the ability to interact with a variety of people outside the institution. Students must know how to collect, collate and analyse information though they may not be able to eliminate irrelevant data to effectively use information. They may have limited capabilities in terms of interpretation except in the case of conventional problems.

Though the project is based on team work, every member of the team should be able to demonstrate the contribution made, new ideas captured, lessons learnt and scope for improvement.

Based on the experiences gained from the mini project and personal interests, students can choose either entrepreneur mode or professional development mode. Those choosing professional development modes will join a company as an intern and will be supervised by one or more adviser from the academia in addition to a supervisor from the company. The main objective of this exercise is to enable the student to enhance his/her professional capabilities by engaging himself/herself in different activities in a work environment and in the process understand how the knowledge and skills gained could be translated in a real time environment. Student will also gain insights into work cultures and ethics in daily life from a professional perspective.

The entrepreneurship mode is available only to those who are interested in becoming entrepreneurs directly or otherwise. Students who choose this mode will be attached to entrepreneurs or others who have activities that have consequences on entrepreneurships. For instance, students may want to know on project finance and hence may be associated with banking sector. In some situations the student may want to know the set of tax benefits and other information, in such situations he could join as intern with an audit firm or tax consultant. In all these initiative the student is expected to build the knowledge and skills that will be useful to become successful entrepreneur.

It needs to be underscored that not all the students choosing the entrepreneur mode are expected to become entrepreneurs. In such situations, students are expected to act as business development managers or support managers. However none of the students in this stream are expected to be in the professional domain, becoming an expert such as network specialist or a cryptographer.

The experiences gained in the industrial internships are expected to lead to the next level of project in the final semester of the programme. In this project, the student is expected to translate whatever he has learnt into realisable products. For instance, a student who on a professional enhancement mode was an intern in a company may develop a security product for the company where he was the intern or develop a product that could be used in similar generic situations.

A student with Math and Software Engineering double major, for instance, would have studied how the company estimates the cost of a project, during his internship in the company. Based on the knowledge gained, the student is expected to develop a software product that could be used to work on software costs in a variety of generic situations. One or more of the mathematical skills he learnt, software products that he used and special and core subjects he studied will help him/her develop a useful product thus demonstrating his/her expertise in the area.

A student with the same double major viz. Math and Software Engineering may want to become entrepreneur. Internship would have helped him/her understand how project costs need to be estimated, risk management, time lines, training for personnel etc. Based on the knowledge gained he/she needs to develop a project report which contains all the key elements required for a software project.

Thus the projects begin as team work and culminate into a product ready for use. The stages of the project could be summarized as the one that begins with a team work in the first phase, engagement through internship in the second phase and results in a ready to use product in the third phase. Peer-learning, mentoring and independence is the path of progression envisaged. All through the process the role of the students and his/her level of participation is redefined. As he/she reaches the last phase his/her contribution to the body of knowledge is substantial, often innovative in nature.

5. Exit awards

All programmes designed under this scheme are designed to broadly address the salient features of Oman National Qualification framework. Nevertheless, the curriculum has been constructed not to replicate available structures or elements. Furthermore, in a general sense, the curriculum has generic components which could be modified to suit any national qualification framework or other prescriptions. The curriculum is based on a credit point system, which needs to be differently organised to suit a credit system.

This is a four year, eight semester programme, with each semester extending over sixteen weeks, with additional time period for final examinations, wherever appropriate. Students can opt for a short semester of equivalent period, thus decreasing the period of study though in general, a four year period is required to complete the programme.

In the case of the Bachelors programme, 480 credit points need to be earned. Approximately 50 per cent of the credit points is realised from the major. Out of this approximately 25 per cent of the curriculum is related to each of the majors. Again, this

25 per cent is roughly distributed over core module (12.5%) specialisation modules (about 10%) and computational skills (about 3%). The general studies component accounts for 6.25% of the credit points and English for Special purposes accounts for 3.125%. All these details are provided in Table 1.

In order to be well equipped for internship a preparatory course covering 2 per cent of the credit points is offered. Students may still choose optional modules in order to be equipped to address the demands of project and internship. For this purpose about 16 per cent of the credit points are from the optional modules.

Table 1 Distribution of credit points over different components: Bachelors programme

Component	Credit points	percentage
Core Math	60	12.5
Core Second Major	60	12.5
Specialisation Math	45	9.375
Specialisation Second Major	45	9.375
Optional modules	80	16.667
Computing skills	30	6.25
General Studies	30	6.25
Preparatory course: entrepreneurship/Professional practice	10	2.08
English	15	3.125
Mini Project	15	3.125
Internship	60	12.5
Final project	30	6.25
Total	480	100

Experiences from a real time environment realised through mini projects, internships and final project contribute close to 20% of the credit points. The mini project which basically is team based is a 15 credit point module, the final project is a 30 credit point module and the internship is a 60 credit point module.

A. Interim Exit Awards

Though the best benefit of the programme is realised upon completion of the entire programme, students are provided interim exit awards for the following reasons: a. students who find the programme difficult may gain advance standing in other programmes and continue their studies b. wherever applicable students may get incentives from the employers, and c. to recognise the work completed till a given point in time with a suitable academic award.

The programme being a double major programme, students with intermediate exits will not be provided any specialisation. Also successful completion of the modules under Math or the specialisation alone will not entitle an award with that specialisation.

Awards upon completion of a specified number of credit points are also considered. Upon successful completion of 120 credit points and 240 credit points a certificate and Diploma are respectively awarded. Upon successful completion of 360 credit points and 480 credit points an Advanced Diploma and Bachelors with double major are awarded. The components from which these credit points need to be acquired are given in the following table:

Table 2 Distribution of Credit points for Interim exit awards

Component	Award Certificate	Award Diploma	Award Adv. Diploma
Core Math	30	45	60
Core second major	30	45	60
Specialisation Math		15	30
Specialisation Second Major		15	30
Optional modules	20	40	80
Computing skills	15	30	30
General Studies	10	20	30
Preparatory course: entrepreneurship/ Professional practice			10
English	15	15	15
Mini Project		15	15
Internship			
Final project			
Total	120	240	360

Students are expected to develop and demonstrate skills in a number of competency areas relating to Math, subject of specialisation in addition to communication skills, ability to assimilate and analyse information from a variety of sources, work in teams as well as independently. Students are expected to have a clear understanding of what they intend doing in terms of professional competence or entrepreneurship.

6. Some perspectives to the programme

Immaterial of its nature and strength, a programme gains acceptance only if it is academically strong, welcome by industry and financially viable in addition to other factors that may affect the quality of the programme.

Aspects such as benchmarking, likely skills that are to be acquired, and students' mobility are to be addressed in the early stages of developing the programme and needs to be continued as an ongoing process. An operable academic structure is equally important. Interestingly, several double major programmes could be constructed with math as one major in such a way that there is an overlapping modular structure.

For instance, with one of the specialisations from *frame* 2 say Insurance, a curriculum with double major Math and Insurance could be designed with several modules that will be common to Math and Software Engineering as well as Math and Insurance.

A central repository containing details of all the modules will be useful for this purpose. Every time a new module is introduced as an optional or general studies or core or specialized subject the same needs to be included in the central repository. Departments may decide to include one or more modules from this repository and develop a new curriculum or replace existing modules.

Usually such a repository helps to integrate students from different classes and offer modules that would be useful to different major. Also, such commonality helps in several other ways. a. students will have opportunities to interact with different groups b. opportunities for understanding complexities in different subject areas c. from scheduling point of view, it becomes easier to schedule a fewer classes with more students d. cost averages with more students in one class, and e. number of teams within a class can be increased and they could work on several issues and share knowledge and experience.

From the point of view of an employer, students with prior experience are usually preferred as training needs can be minimized. Also with double major, employers have students who have the necessary skills and knowledge in two different major, usually linked to each other in a critical way.

The proposed curriculum does not call for establishing expensive labs which need to be maintained, though there are lab requirements. The major investment will be in making the programme visible through appropriate marketing strategies and investing in human resources to attract the best talent who provide the desired results. Also investment is required to train members of faculty in emerging technologies and supporting junior staff to enhance their qualifications and other skills.

Tie-up with industries is key to the success of this programme which depends on learning from real time environment through internships and projects. Appropriate strategies and investments are required in order to build strong industrial relations and to rapidly absorb the needs of the industry.

7. Limitations and further studies

It must be noted that the curriculum needs to be popularised very carefully as there is scope for misunderstanding in terms of the specialisations etc. The full benefit of the programme is best achieved only upon completion of the entire four year programme.

Interim exits are not likely to benefit students or the employers as much as the complete programme is expected to. Hence counseling for the programme needs to be strengthened.

Students who join the programme need to be highly motivated, with very clear career goals. They should be able to spend substantial time. In some situations they will have to invest in terms of financial resources to make benefit of their project. This needs to be offered as a full time programme and is not suitable for working students though students who join the programme with prior work experience stand to gain.

It will be useful to study the impact this programme can make for students in different regions. A detailed comparison of existing double majors which do not have Math as one would also prove useful in identifying the positioning of the proposed programme in relation to other programmes. From a financial perspective, a detailed financial analysis with minimum student strength, infrastructure and other facilities required will be helpful. Options to benchmark the programme with available indicators will strengthen the programme from an international perspective.

8. Conclusion

A double major programme with Math as a major is an appropriate approach considering the growing demand for people who have a rigorous training in Math and a related area. Several applications have emerged from the theoretical underpinnings and other developments in Math underscoring the need for institutions to offer interdisciplinary programmes with Math as one. It has resulted in synergies of different disciplines leading to graduates who are creative and exploratory beyond known and conventional skills.

A double major will also provide a *safety net* when one fails. When, for instance, global changes or industrial patterns or technology affects opportunities for graduates in one subject area, the other will be an available choice for the student to look for opportunities. Such an opportunity may not be available to a student whose skills and knowledge are confined to a single discipline. Thus a double major will add value to a student and make him more marketable.

It is important that different stakeholders realise that a double major programme with Math as one will develop students who would be successful as entrepreneurs or as professionals considering the growing demand for professional who have strong Math background. Furthermore, such groups will contribute to fundamental research that will have a bearing on real time applications which increase efficiency and productivity.

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