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Education and Software Engineering

Ten Years of Progress towards a Recognised Professional Discipline

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Abstract: The discipline of Software Engineering has a history dating back to 1968. However, it is only during the last ten years that real efforts have been made to address it as a profession with appropriate educational support at university levels. The achievements and failures regarding movements in the US towards professionalism in the latter half of the 1990s are first considered. Then parallel and subsequent activities that have taken place on a broader front under the auspices of the International Federation for Information Processing (IFIP) are reported. The framework that the IFIP work has produced is then used in an evaluation of international progress over a ten-year period. Finally a summary of remaining challenges is given.

1. Introduction

The formal history of the discipline of Software Engineering (SE) can be traced back to the 1968 NATO (North Atlantic Treaty Organisation) Conference on Software Engineering [15] where the first organised presentations and discussions took place. However, it was not until the late 1970's that the first academic programs in SE were offered. The programs, at masters level, were created at a number of universities in the USA and were based on the results of an effort initiated by the IEEE-Computer Society (IEEE-CS) [8]. Undergraduate courses began to appear in the UK and Australia during the 1980s but did not appear in the US until much later. The first two programs in the UK were at Imperial College in London in 1985 [7] and at the University of Sheffield in 1988 [5]. Also, during the 1980s the first text books aimed specifically at SE began to be published. For

example, the first edition of Sommerville's text "Software Engineering" [20] appeared in 1982 – by 2004 it was in its seventh edition and had grown immensely both in size and popularity. With regard to conferences addressing the educational and professional side of SE there are the long running Conferences on Software Engineering Education and Training (CSEET) that began in 1987. These were initially run and sponsored by the SEI (Software Engineering Institute) at Carnegie Mellon University but now operate under the auspices of the IEEE-CS. However, it was not until the 17th conference in 2004 that they started to be held outside the North American continent. During the 1990s, there were also a number of national and international SE specific events, outside the US, that have had streams that addressed education and professional issues. For example, the IFIP 1993 Working Conference in Hong Kong [4] and the UK 1996 conference on Professional Awareness in Software Engineering held in London [14].

It is very clear that it was only from the mid 1990s that real efforts were being made to address SE as a professional discipline with appropriate educational support at university levels. The remainder of this paper addresses the progress and otherwise that has occurred during the last decade. In section two I consider the achievements and failures regarding movements in the US towards establishing SE as a profession in the latter half of the 1990s. Then in section three I outline some parallel and subsequent activities that were taking place on a broader front under the auspices of the International Federation for Information Processing (IFIP). This work has provided a framework that can be used in evaluating the progress that has been made within SE. In section four, I highlight the successes that have been achieved and finally in section five I present what I believe are the remaining challenges.

2. Achievements and Failures 1996-2000

In January 1996 Gary Ford and Norman Gibbs produced a SEI report entitled "A Mature Profession of Software Engineering" [9]. In this they proposed a model that they believed would characterise a mature profession. They also presented a general exploration and validation of their model using professions that existed at the time. Finally they used their model to describe what they believed could become a SE profession. The components of a profession and the interactions between them, as identified by Ford and Gibbs are reproduced in Figure 1. However, a major problem with this work is that it took a very US-centric view. Only in one of its appendices was a non-US situation considered and that was with regard to undergraduate SE programs. Also, there was perhaps an overemphasis on the mechanics of controlling a profession rather than what a profession should be about.

At the time of the Ford and Gibbs report the IEEE Computer Society (IEEE-CS) and the Association for Computer Machinery (ACM) were already working together

towards establishing SE as a profession and there is no doubt that the report fed into this. In 1998, the IEEE-CS and ACM further formalised their co-operation with the creation of Software Engineering Coordinating Committee (SWECC), which was made responsible for coordinating, sponsoring and fostering all the various activities regarding SE. within the IEEE-CS and ACM's sphere of operation. These included areas such as standards of practice and ethics, body of knowledge, curriculum guidelines, and exam guidelines. Particular projects that SWECC promoted, and which I will return to later in this paper, were the project concerned with defining a Software Engineering Code of Ethics and Professional Practice [17], and the project concerned with defining a Software Engineering Body of Knowledge [22] – the SWEBOK project.

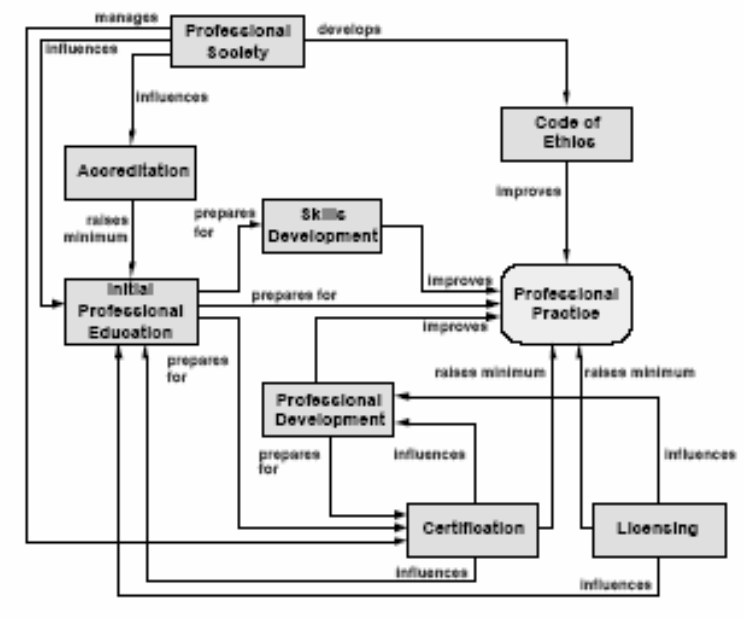

Fig. 1. Ford and Gibbs representation of the interactions among the components of a profession [9].

Then in June 1998 an event occurred that would cause a divergence of views on SE professionalism between the IEEE-CS and the ACM and which would eventually lead to the latter's withdrawal from SWEECC [2]. This event, which at fist appeared so positive, was the enactment by the Texas Board of Professional Engineers rules that recognised SE as a distinct engineering discipline [21]. These rules went into effect on 18th July 1998 and applications for licenses were accepted from 1st August 1998. This legislation enabled engineering licenses to be issued to

Software Engineers so that they could, within the State of Texas, legally represent themselves to the general public as an engineer, offer consulting engineering services to private and public entities, and perform engineering design or construction on public works. Unfortunately, a influential group within the ACM felt that that SE was not yet a mature discipline, that licensing was inappropriate at that time, and that the SWEBOK could be seen to be too closely related to the examinations that licensing would involve [2].

During 1999 and 2000, perhaps as a reflection of the growing rift between the ACM and IEEE-CS interest in SE professionalism appeared to wax and wane. Some papers relating to the topic appeared in major computing journals [e.g. 3, 10, 12, and 16]. However, at least in the US, a commonly held view was that professionalism was a "dead duck" [6].

3. IFIP's 1998 Framework for Professionalism

During the 1990's, independently of the work that was being undertaken by IEEE-CS and the ACM, the International Federation for Information Processing (IFIP) started to address issues that were related to the movement of Information Technology professionals from one country to another. A driver behind this was a view from the World Trade Organisation that the establishment of standards regarding the qualifications of computing professionals was very important in an era of international treaties that promoted free trade and the free movement of workers from one country to another. IFIP was ideally suited to work in an area concerned with issues regarding professional standards and their harmonization because of its truly international nature. In 1997 the IFIP Executive Board handed the work on professional standards to a working party within the Technical Committee on Education (TC3). Their task was to produce a document that would clearly set out the standards of tertiary education, experience or practice, ethics, and continuing education that a customer might expect from a practitioner offering services to the public. This document, it was hoped, could be used by the International Standards Organisation and IFIP's member bodies to gain a consensus standard that could then be adopted by the standards bodies within each country. It was expected that the IFIP Member societies would administer the standard within their countries, giving the Member societies increased status and authority. During 1998 a small writing party met to produce a draft standard [13] - a copy of the text of which is appended to this paper. The main parts of the draft address the following areas:

- Ethics of professional practice,
- Established body of knowledge,
- Education and training,
- Professional experience,
- Best practice and proven methodologies and
- Maintenance of competence.

The draft was presented in August 1999 to the full TC3 committee meeting in Irvine, USA. At IFIP's World Computer Congress held in Beijing in August 2000 the harmonization project was re-considered within TC3 and it was decided to refer the draft document back to the Working Group concerned with Professional and Vocational Education (WG3.4) for further work to be undertaken.

It was felt that the most appropriate area within the field of Information Processing for consideration of professionalism was SE. This, starting in September 2000 a series of activities were undertaken to promote the IFIP Harmonization document and provide a forum for an analysis of its relevance to SE. These activities included conference presentations, panel sessions, participative workshops, and an International Summit that was co-located with the 2002 International Conference on Software Engineering (ICSE). It is estimated that these activities brought the IFIP Harmonization document to the direct attention of at least 350 individuals within the SE community and many more indirectly via conference proceedings and the workshop/summit reports. The overall reaction by the community was very encouraging. It has been recognised that the harmonization document essentially defines framework or meta model, which should truly assist advancing professional standards if it is used in a sensitive and appropriate manner. A summary of the work undertaken in promoting and evaluating the harmonization document and the most significant outcomes from the evaluations was included in paper [24] presented at the IFIP 2005 World Conference on Computers in Education.

4. Evaluations of Progress Against the IFIP Model

There are obviously similarities between what was proposed by Ford and Gibbs and the model in the IFIP Harmonization document. Perhaps the greatest differences are in the areas of controlling the profession and education. Regarding the former, the IFIP document says little since it would see this as the role of the member society or legislative body within the relevant country. However, it does place a greater emphasis on the underpinning of education both at university and during life long learning by an appropriate Body of Knowledge, recognised Best Practices and Proven Methodologies. To measure progress towards achieving a recognised professional discipline for SE evaluations can be performed against the six areas highlighted in the document. However, because of the close relationships between particular areas in some cases I will consider two or more together.

4.1 Ethics of professional practice

A major success that did result from the SWECC cooperation between the EEE-CS/ACM was the production of the Software Engineering Code of Ethics and

Professional Practice by a task force led by Don Gotterbarn of East Tennessee State University. The code is available [17] in two forms: a short version, which summarises aspirations at a high level of abstraction, and a full version which includes additional clauses. The latter provide examples and details of how the aspirations of the code should change the way persons act as SE professionals. Currently the eight areas that the code addresses are: Public, Client and Employer, Product, Judgment, Management, Profession, Colleagues, and Self.

The code in addition to being approved by both IEEE-CS and the ACM [11] has been widely adopted across the world [17]. In fact, it appears to be one particular project that has been outstanding in the lack of criticism associated with it. Perhaps this was partly due to the way it was developed and those involved [11].

4.2 Education and life-long learning

Three areas within the IFIP Harmonizsation document address education and what can be seen as life long learning activities. These are the sections on: Education and Training (which relates to undergraduate level activities), Professional Experience (which relates to supervised experience that normally follows graduation), and Maintenance of Competence (which relates to the learning and associated activities that practitioners should undertake throughout their professional lives so as to remain competent in the tasks that they undertake). The major success in the area of education has been the publication in August 2004 of the SE Volume of the IEEE-CS/ACM Computing Curricula [18]. Of particular note is the process that was adopted in the production of this volume. In addition to the direct work of four groups of volunteers (a Steering Committee, an Advisory Board, an Education Knowledge Area Group, and a Pedagogy Focus Group) there has been a particularly open development process which has attempted to involve as much of the community as possible via: public reviews by the SE community, invited reviews by recognised experts in the field, presentations at conferences to keep the community informed, articles in community publications, such ACM SIGSOFT Software Engineering Notes, open participative meetings and workshops at major conferences, including the 2002 and 2003 International Conferences on Software Engineering, which provided opportunities to provide information, carry out activities, and generate feedback. The work of the Education Knowledge Area Group was also supported by a major workshop that was partly funded by the National Science Foundation.

To close the loop on comments received, the project's web site contains a record of all the individual comments and the developers' responses to them [19]. This approach, the tools used to support the work, and the level of international participation in the effort have been formally recognised in the 2004 annual report of the ACM Education Board as setting standards for the development practices for all future generation ACM-sponsored curriculum guidelines. The production of

SE2004 Volume really is a major success as it can be seen to have given the SE discipline international academic credibility it so rightly deserves.

4.3 Knowledge

Two areas within the IFIP Harmonization document relate to the knowledge domain for Software Engineers. These are the area headed Established Body of Knowledge, and that headed Best Practice and Proven Methodologies. For a discipline which a few years ago had no agreed body of knowledge we could now view ourselves as being doubly lucky in that we now have two complementary expositions. First we have the SWEBOK [22, 23], of which mention has already been made in section 2 of this paper, and which provides a guide to the core knowledge that a practitioner with some four years of work experience should have access to. Secondly we have the Software Engineering Education Knowledge (SEEK) which forms an essential part of the Curriculum Document [18] and represents the knowledge appropriate to undergraduate study.

To a great extent those who have been involved with the SWEBOK project may be regarded as having been extremely unlucky in that it was viewed as a key element in the split between the ACM and IEEE-CS over licensing and the ACM's withdrawal from SWECC. The leaders of the project are to be congratulated for seeing the project to a stage where not only has the SWEBOK guide been published under the auspices of IEEE-CS [23] but it has also been adopted as a technical report by ISO (ISO/IEC TR 19759) [22]. The project has attempted to adopt a broad and international approach in the reviewing and of particular note is that the results of the process have been visible and are available on the project's web site. A milestone has clearly been reached with the production of the 2004 version of the guide. The developers are now embarking on the planned evolution phase of the Guide [22].

5. Outstanding Challenges

From the information presented in the previous section, one may infer that all is well and everything is a success. Unfortunately, this is not quite the case. The evaluations undertaken on the proposals in the IFIP Harmonization document [24] resulted in many positive outcomes the major of which was the acceptance of the framework itself. However, the area of Best Practices and Proven Methodologies was seen as particularly problematic. With questions being raised such as:

- How to test for "best practice"?
- How to enforce documentation of Best Practice and Proven Methodologies?
- Should it build upon existing standards?

The ongoing problems associated with poor quality software continues to be highlighted in published studies [1] and the indications are that if Best Practices do exist they are certainly not used as they should be, nor does it appear that they are being developed in the light of actual practical experiences.

Acknowledgements

This summary draws in parts from papers and reports which myself or myself and my colleague Prof. H. Edwards have produced relating to evaluations of the IFIP Harmonization document. Details of all these can be found in the reference list of the report presented to the 8th IFIP World Congress on Computers in Education [24].

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Appendix
IFIP Harmonization Document

Harmonization of Professional Standards
Draft: October 1998
Summary
This document sets out an international standard for professional practice in information technology.
Practitioners who meet the standards will:

- publicly ascribe a code of ethics published within the standard.
- be aware of and have access to a well-documented current body of knowledge relevant to the domain of practice.
- have a mastery of the body of knowledge at the baccalaureate level.
- have a minimum of the equivalent of two years supervised experience before the practitioner operates unsupervised.
- be familiar with current best practice and relevant proven methodologies.
- be able to provide evidence of their maintenance of competence.

Purpose
The purpose of this work is to clearly set out an international standard for professional practice in information technology.
The components of the standards are:

- Ethics of professional practice,
- Established body of knowledge,
- Education and training,
- Professional experience,
- Best practice and proven methodologies and
- Maintenance of competence.

A customer has a right to expect that a practitioner offering information technology services to the public meets these standards.
This document will be offered as a draft standard to the International Standards Organization in anticipation that it will in turn conduct its process of obtaining consensus from its member bodies and hence the standard would be adopted by the standards bodies within each country.
It is expected that the IFIP member societies would prepare any local or regional adaptation of the standard. The administration process, which may include promotion, assessment and certification as well as the distribution of materials, may also be carried out by the IFIP member society.
The standard could also be incorporated in the requirements for a level of qualification of individual members in the member society.
Although the initial country or regional implementations may have differences, the intent is to move towards a common implementation.

Why Have Professional Standards?
The traditional professions such as accounting, medicine and engineering have long had standards which enable a qualification gained in one country to be recognised in another. The World Trade Organisation in conjunction with the International Standards Organisation has now taken an active role to create such standards under the General Agreement on Trade in Services (GATS).

The benefits of internationally recognised standards are that:

- the public is assured that safety or economically critical work is performed by competent individuals regardless of where in the world those persons gained their qualifications and experience.
- a client is assured that a person who meets such international standards is competent to carry out tasks in documented specific areas regardless of where the work is done or the output of the work is used (subject to recognition of issues of culture and locale).
- professionals are assured that their qualifications if recognised in one country will be accepted in other countries without re-examination (except possibly for being up-to-date).
- Under GATS, trade in products developed by practitioners who meet this standard cannot be restricted on the grounds that the developers were not competent or used inadequate professional practices.

Such standards will contribute to the attainment of a reputation for competence by the profession.

The standards will facilitate the obtaining of work by individual practitioners in the international arena.

To Whom does the Standard Apply?

This standard is primarily focused on practitioners involved in the development of software-based systems and related services. The standards are not necessarily intended to apply to other members of IFIP member societies such as:

- academics, who in general will be much more qualified but possibly in a narrow discipline and whose research may be at a more abstract level than practice.
- school teachers, who in general will be qualified to teach rather than to develop IT systems.
- users, who have input into the designs of computer systems but who do not construct them.
- electronic engineers, who design computers but who would normally be qualified as engineers.

It is recognized that these classifications may be blurred.

Harmonization of Professional Standards

The following clarifications are offered in this context.

Harmonization means that the standards of different countries would be brought together to be substantially the same. Any extremes from the commonality of these standards would gradually be pruned away until each country has the same standard by mutual consent.

Professional identifies the peculiar responsibility of a person with high levels of knowledge and related practical skills in a given discipline with respect to members of the public who do not have that knowledge or skill-set. It is particularly relevant to the information technology profession because it has significant impact on society at large. The power of the knowledge must be balanced by a sense of responsibility towards others. This definition is focused on practitioners, persons who actually develop, maintain and operate software systems for commercial or governmental purposes.

Standards are clear statements that reflect the minimum qualifications for mastery and knowledge of processes, skills and practice that a professional should have before undertaking work which may put an employer or client at risk, either physical or financial.

The field of Information Processing has many domains ranging from data management to embedded software systems. Any one individual cannot be expected to be expert in more than one or a few such domains. This needs to be recognized particularly in the body of knowledge required to be known by one person.

The changes within the many domains together with the dynamic development of new domains in information technology means that the standards themselves must be continuously developed and individuals must anticipate life-long learning.

The Standard for Professional Practice in Information Technology

Ethics of Professional Practice
A code of ethics acknowledges the professional responsibilities of practitioners to society at large, members of the public, employers, contracting parties and fellow practitioners.
Codes of ethics have been published by many member societies and IFIP itself.
Every implementation of the standard must include a code of ethics.
Such a Code of Ethics must be compatible with the culture of the society in which the practitioner normally works.
Practitioners must operate in a manner compatible with the culture of the locale in which they are currently working and in which the product may be used.
Practitioners must publicly ascribe to the code of ethics published within the standard.

Established Body of Knowledge
Several IFIP member societies have published bodies of knowledge, some of which have gained wide acceptance. Such recognised bodies of knowledge are divided into many domains determined by the various services carried out by practitioners. The body of knowledge on which any implementation is based should include at least the common components of these but also ensure that each domain is complete in itself for the domains adopted locally.
Mastery of such a body of knowledge forms the basis of preparation for practice. A practitioner must demonstrate mastery of at least one such domain as well as all core components identified in the body of knowledge.
Practitioners must be aware of and have access to a well-documented current body of knowledge relevant to the domain of practice.

Education and Training
Most practitioners will enter the workforce with prior education and training which will commonly be a baccalaureate degree assessing the mastery of the body of knowledge.
Institutions offering such education and training should be prepared to openly compare themselves to internationally well-known and recognised peer institutions offering similar programmes.
It is recognised that this level of mastery may be achieved by various combinations of education and experience. Nevertheless a practitioner must be able to provide evidence of such mastery to practitioners who have met this standard.
The minimum level of mastery of the body of knowledge must be at the baccalaureate level.

Professional Experience
Experience builds on knowledge in many essential ways. Such as:

- It develops and improves practical skills and competencies.
- It provides understanding of task definition in the users' terms.
- It helps develop interpersonal skills that facilitate the communication and human interaction between all participants.
- As many approaches to problem solution are not readily scaleable experience over a wide variety of problem types and sizes is desirable before working in an unsupervised environment. Experience is generally required in assessing task complexity.

- Task management, overall project management and quality management generally require experience.

Other professions have clear requirements for experience before allowing their members to practice without supervision.
In addition to a demonstrated mastery of the body of knowledge a minimum of the equivalent of two years supervised experience is recommended before the practitioner operates unsupervised.

Best Practice and Proven Methodologies
Experienced practitioners have identified and documented many practices and methodologies the use of which generally leads to successful project outcomes. Where such best practice and proven methodologies are available the practitioner should use them unless a particular task has exceptional attributes.
Member societies drawing on all available international sources should encourage the documentation and promulgation of best practice and proven methodologies.
Practitioners should be familiar with current best practice and relevant proven methodologies.

Maintenance of Competence
To maintain demonstrated competence practitioners must be familiar with new developments in their domains of practice.
Such developments may be reflected in the body of knowledge, best practice and proven methodologies as well as in specific skills.
Familiarity with new developments may be obtained through formal education or peer interaction.
There may be assessment of current competence by formal examination, peer assessment or employer or client acknowledgement of successful work.
A practitioner should participate for at least the equivalent of 10 days per year in activities that contribute to maintaining competence. It is recognised that in different locations the opportunities for such ongoing development may vary.
The standard in each country or region must state how this requirement will be met and the role of the IFIP member society in monitoring this function.
Practitioners must be able to provide evidence of their maintenance of competence.

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