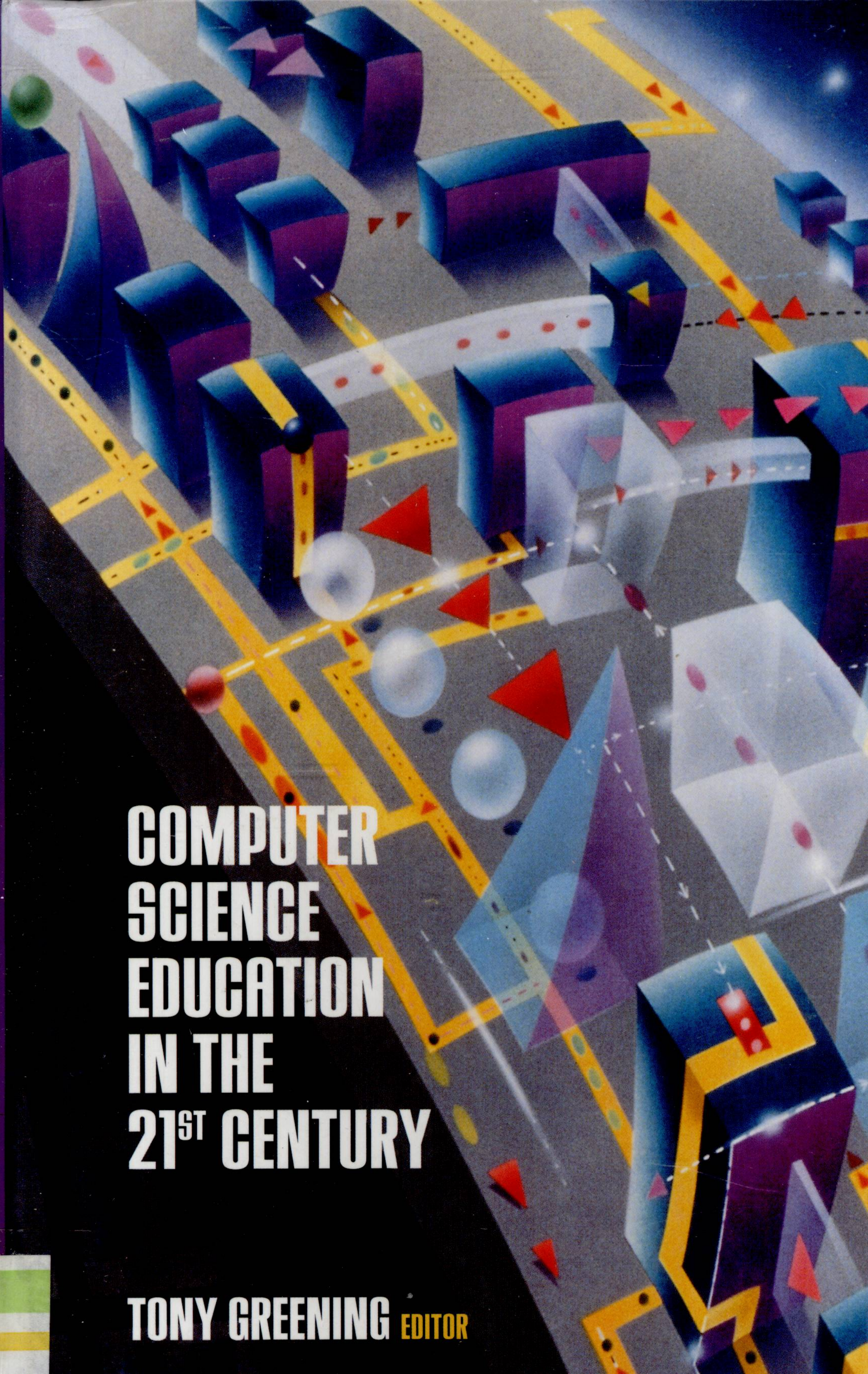

COMPUTER SCIENCE EDUCATION IN THE 21ST CENTURY

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Editor

Computer Science Education in the 21st Century

With 33 Illustrations

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Computer Science Education in the 21st Century

An Invitation …

It seems reasonable to suggest that the future is in some way based on what we articulate it to be in the present, and that today's negotiations with the future help to shape its final form. To act with a sense of purpose requires some degree of interaction with the future. Conversely, the future provides context to our present behavior.

This belief formed an early motivation for this book. It contains the work of a number of computer science educators who were prepared to actively engage with the future of their discipline and to share their sense of vision of it.

Collectively, it represents a small statement in an ongoing dialogue. The vitality of computer science—and its consequent tendency to diversify—ensures that no single part of this dialogue fully represents the status of CS education as it moves into the future. The delivery of this initial collection of papers is intended to open an arena in which continuing discussion of the future of computer science education is encouraged. The intention is therefore to publish occasional collections that add to the dialogue. In the process, I believe, we will find ourselves blessed with a multitude of exciting futures for CS education. The true value of this process will never be in terms of something as static and drab—nor as singular—as implied by the concept of prophecy. Rather, it will be found within the dynamic of the activity itself—the process of engagement with the future, and with the visions that others have of it. Answers have little sense of finality in such an environment; instead they serve to generate new cascades of inquiry. New potential is not far behind.

That some engaging questions have been raised by the contributions to this book is some measure of its success, by the standards just presented. But it is also an opportunity for response. There are also alternatives to be presented, causes to be championed, gaps in content to be filled—a dialogue to be had.

In short—"Contributions are most welcome!"

Contact with the editor for this purpose may be made via e-mail to agreening@acm.org.

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Abbreviations

4Gl	4th Generation Language
AAAI	American Association for Artificial Intelligence
ACM	Association for Computing Machinery
ACS	Australian Computer Society
ADT	Abstract Data Type
ATM	Asynchronous Transfer Mode
CASE	Computer-Aided System(s) Engineering
CERN	European Laboratory for Particle Physics
CS	Computer Science
CS1	Computer Science I
DVD	Digital Video Disc
FASE	Forum for Advancing Software Engineering
FTP	File Transfer Protocol
IEEE	Institute of Electrical & Electronics Engineers
IEEECS	Institute of Electrical and Electronics Engineers Computer Society
ISDN	Integrated Services Digital Network
ITiCSE	Innovation and Technology in Computer Science Education
MOO	MUD Object Oriented
MUD	Multi-User Dimension/Domain/Dungeon
NEELB	North Eastern Education and Literary Board
NSF	National Science Foundation
OCR	Optical Character Recognition
OODBMS	Object-Oriented Database Management System
PARC	Palo Alto Research Center
PE	Programming Environment
RDBMS	Relational Data Base Management System
SIAM	Society for Industrial & Applied Mathematics
SGML	Standard Generalized Markup Language
SIGCSE	Special Interest Group on Computer Science Education
VLSI	Very Large-Scale Integration
Y2K	Year 2000

Contents

Computer Science Educational Futures: The Nature of 2020 "Foresight"

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This book considers the effects of change within computer science education. The targeted future, the year 2020, was chosen to be distant enough to encourage contributing authors to risk being visionary, while being close enough to ensure some anchorage to reality. The result is a scholarly set of contributions expressing the visions, hopes, concerns, predictions and trend analyses of the future of a discipline that continues to impact greatly on the wider community.

The initial approach to potential contributors was as unconstrained as possible. It was established that the subject matter could be as broad as the content of that icon of computer science education, the annual Association for Computing Machinery (ACM) Special Interest Group in Computer Science Education (SIGCSE) conference. The only additional constraint was that it ultimately be cast in terms of the future.

The factors that make this collection interesting are:

1. *The standing of the contributors:* A selective call for contributions was made, with e-mail being sent to authors who had previously considered the future of computing or computer science education in their published works.
2. *The blind nature of the contributions:* The contributors did not have information about the work of other authors.
3. *The unconstrained basis of the project:* The call for contributions was unconstrained with respect to content.
4. *Methodological freedom:* Contributions were also unconstrained with respect to methodology. Potential authors were advised that their chapter need not be predictive (or prophetic) in nature, although it might well be. Suggestions were made regarding methodologies for

dealing with the future, which included extrapolation, scenario development, prescriptive (critical) analysis, and reflection.

5. *Future focus:* The context was the year 2020. This encouraged authors to lower their guard a little, without abandoning scholarly process.
6. *The "seeding" effect of the project*: The contributions to this book are part of an ongoing process. They will variously stimulate, agitate, excite, bemuse, annoy or inspire its readership. These responses are actively sought, and readers are encouraged to enter the dialogue.

1. Paradigms for the Future

Futurism is an uncomfortable domain if one seeks only to exercise prophecy. For example, in 1989 one author wrote a book that focussed on the next 200 years and felt compelled to produce a revised version only three years later (Wagar, 1994). Another example may be the gloomy predictions made in the recent past regarding the future of the Internet (McRae, 1996).

On the other hand, the current book explicitly states an intention to occasionally repeat the exercise in the future. Given this, a certain amount of prophecy will provide a basis for a retrospective analysis that may prove quite educational. However, the value of the contributions to this book exceeds their ability to foreshadow important features in computer science education. In order to position the worth of these contributions properly, a quick tour of possible approaches to studying the future is presented.

These approaches are referred to here as "paradigms." This use of the word reflects a belief that they are of such a fundamental nature that they determine the very questions that are regarded as valid and therefore lead to different "world views" with respect to research. The extent of this is captured by Guba and Lincoln (1991, p. 80), who express the pervasiveness of paradigms by defining them as

> …basic belief systems; they cannot be proven or disproven, but they represent the most fundamental positions we are willing to take. If we cite reasons why some particular paradigm should be preferred, then those reasons would form an even more basic set of beliefs. At some level we must stop giving reasons and simply accept wherever we are as our basic belief set—our paradigm…

Three paradigms are presented briefly—the positivistic, the interpretivistic, and the critical. Given the definition of paradigm in terms of its fundamentality, the reader is expected to identify with one more than others, and possibly to feel quite antagonistic to the suggestion that some of these have any sense of legitimacy.

1.1. The positivistic paradigm

The material of interest in the positivistic approach is the empirical world. Positivistic researchers therefore learn to "see" what is measurable (Slaughter, 1989). Through the discovery of empirical indicators, the future is measured and controlled.

Ogilvy (1996) summarizes the positivistic paradigm in four propositions:

1. Empirically measurable elements form the basis of all activity.
2. Universal laws determine all spatio-temporal activity.
3. The above points subsume complex activities such as human thought or biological growth. Thus, understanding (and predicting) such activities requires a decomposition into fundamental elements—simplifying the activity—and then applying those elements to established patterns of causality.
4. Perhaps new laws are required. Confirmation of them occurs as a test of predictive power. If a set of laws can be used upon a set of antecedents and successfully predict an outcome, then the laws are confirmed. The predicted event is then regarded as explained and understood by science.

Positivism may be assumed to be the default research paradigm and the one with the longest written history. As such, it has a visibility that attracts a lot of criticism. One of the criticisms of a positivistic approach to technological futures is that it adopts the essentialist position that technology is symbolically neutral, whereas good arguments exist for the proposition that some of the most important aspects of technology are intangible (Slaughter, 1996). As an extension of this, positivistic research on educational technology, for example, is unlikely to examine the societal embeddedness of technology.

The result of positivism's deterministic world view is that it tends to be accompanied by a vision of evolutionary linearity. If the universe is perceived as having a Newtonian clockwork nature, then the future consists of solving a puzzle with essentially a single solution, although the human experience on the pathway to that solution may indeed be nonoptimal.

1.2. The interpretivistic paradigm

The default positivistic emphasis on that which is tangible leads to a position in which the immaterial tends to be bypassed, and in the process the importance of ideas and meanings as precursors and modifiers of actions is often misplaced (Slaughter, 1989).

The interpretivistic focus is on the understanding of meanings given to futures rather than on the prediction or attempts at empirical derivation of such.

Ogilvy (1996, pp. 41–42) provides a statement that could be used in describing the interpretivistic paradigm:

> Forget about the laws-and-causes approach toward a predictive science. Focus instead on multiple interpretations of the present. This, after all, is what a set of scenarios amount to: alternative interpretations of the present as the first chapter of several very different narratives. Today's decisions and events take on different *meanings* depending on the different tomorrows that are their possible consequences. Contemporary anthropology has made this shift from a positivistic emulation of the hard sciences toward a more literary, narrative approach—what Geertz calls *thick description*: a storytelling approach that stresses the narrative relationships among specific details more than general laws or universal principles.

Ogilvy refers to a movement in the social sciences from a "things"-based (or realist) ontology inherited from positivistic history to a relationships-based one. The positivistic approach may be typified by the reductionist thinking adopted within behaviorist psychology, and it may be compared to holistic approaches in which the interrelating whole is the focus (leading to considerations of the relationships contained therein). From within the interpretivistic paradigm, the participants in a scenario are frequently referred to as "actors," and it is the roles that they assume, and the personal meanings that they bring to such roles, that are of paramount interest.

1.3. The critical paradigm

A criticism commonly leveled at positivism is that it assumes—rather than challenges—the conditions of the present. In such a way, positivism can be regarded as self-perpetuating, in that the default conditions have remained those based on positivistic assumptions. Furthermore, critical theorists will point to the fact that positivistic assumptions about objectivity and value-free perceptions are incorrect (e.g., Hutchinson, 1992).

By way of example, Pohl (1996) favors *inventing* the future rather than trying to predict it. Methodologies that some might associate with a noncritical paradigm—such as Delphi, predictive extrapolation, or scenario development—are used in conjunction with a value weighting. This approach, sometimes referred to as *normative forecasting*, provides a basis for developing policies for actively pursuing those futures perceived as attractive and avoiding those seen as undesirable. Bell (1996, p. 12) states that:

> Some futures are better than others.... For futurists, this is a salient assumption, because they explicitly explore preferable futures as well as possible and probable futures. People judge the consequences of their own and others' acts as more or less desirable.

> Values—the standards by which good and bad are defined—are part of the steering mechanisms both of individuals and groups as they make their way in the world. Thus, part of the futurist task is to study, explicate, evaluate, and even formulate the criteria people use to make evaluative judgements of alternative futures.

Critical futures thinking adopts the position that many of today's issues stem from deep levels in society's structures. As a result, a critical perspective may help find futures solutions at these same deep levels.

2. How to Read this Book

Although a diversity of paradigms is not necessarily evident in reading this book, the discussion above—which may appear tangential—prepares some important ground for the reader.

First, it suggests options for engaging with the papers presented here. Reading the book through interpretivistic glasses offers a perspective of the present as much as it does of the future. We are witnessing a period in the growth of computer science in which it is difficult to gather a sense of understanding about its present status, such is the rate of change. In this climate, a sense of the present status of the discipline may be (paradoxically) better determined by asking a computer scientist to reflect on its future than on its present. Time provides a buffering effect from the turmoil that surrounds vigorous growth. An interpretivistic reading of this book will reveal that it is as much about the present as it is about the future.

Second, it widens the range of response mechanisms to this book, opening up the dialogue to wider interpretations of what it means to consider the future of an academic discipline. Reflection is as valued a contribution as extrapolation from historical events. Contributors to future incarnations of this book should not be intimidated by the belief that this dialogue is paradigm-specific.

Finally, I regard a multiparadigm future of computer science education as likelihood. Already, CS education exercises a much wider range of research methodologies than most of its sibling subdisciplines in computer science. At a major conference—such as SIGCSE—there would be representatives from each of the research paradigms referred to here. Although positivism remains the default, educators in computer science appear to possess a willingness to accept diversity in their research base. This is not to suggest that we each leap from one paradigm to another (or that we are able to!), but rather to propose that we sense some worth in the multiple world views that present themselves in our discipline. It promises a very stimulating future for computer science education.

Hopefully, you will find some of that stimulus within the contributions made to this first book.

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Computing Education 2020: Balancing Diversity with Cooperation and Consistency

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Consider two possible scenarios for the computing education community twenty years from now:

1. The various computing-related degree programs are cooperating in order to be a strong, cohesive part of the overall academic community, while still allowing for a diversity of programs, each one satisfying a different need in the workplace. Faculty, staff, and resources are sufficient to meet the needs of both majors and nonmajors in order to produce the type of graduates needed in 2020.
2. The various computing-related degree programs are working independently of each other, often at cross-purposes, vying for the same resources and students. There is duplication both of subjects taught by the different programs and of efforts in several other areas. The various programs are understaffed and lack sufficient resources to meet student and industry demand.

Current initiatives will make the next five years critical in determining whether computing education twenty years from now will be more like the first scenario or the second. Obviously, the former scenario is more desirable than the latter; however, the computing education community has become increasingly fragmented over the years, which makes a climate of consistency and cooperation more difficult.

Yet there have also been some signs that indicate the willingness of different computing programs to work together for the common good. This article will outline how the computing education community has fragmented over the past twenty to thirty years, what the goals should be to achieve effective computing