

**Guest Editor's Introduction****PSYCHOLOGY OF PROGRAMMING: LOOKING INTO  
PROGRAMMERS' HEADS**

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Psychology of programming (PoP) is an interdisciplinary area that covers research into computer programmers' cognition; tools and methods for programming related activities; and programming education. The origins of PoP date back to late 1970s and early 1980s, when researchers realized that programming tools and technologies should not be evaluated based on their computational power only, but also on their usability from the human point of view, that is, based on their cognitive effects. The hope of such a new approach was that programmers would make fewer errors, produce better software, and work more efficiently. In the first Workshop on Empirical Studies of Programmers, Ben Shneiderman listed "several important destinations for researchers: refining the use of current languages, improving present and future languages, developing special purpose languages, and improving tools and methods" (Shneiderman, 1986, p. 1). During the past two decades, the flow of new languages, tools, and methods has increased rapidly, the scope of programming work has expanded, and research interests have extended to cover group activities. Yet the main goal of PoP—to assist programmers through the benefits of cognitive research—has remained.

The PoP research community consists of cognitive psychologists and computer scientists. The main motivation for computer scientists is the improvement of current tools and the development of new ones, as well as the discovery of general principles concerning humans in the context of programming tasks. Psychologists are interested in new theories of human cognition applicable in other domains too. For them programming—a highly complicated task—provides good opportunities to study high-level cognitive processes in a complex setting. This dual character of PoP manifests itself also in the skills required from researchers: a good knowledge of both cognitive psychology and programming or, better still, psychology, social sciences, and software engineering.

On the other hand, PoP research results are not necessarily limited to the programming domain, but can be applied in other domains that involve design activities in a formal environment. As an example, consider cognitive dimensions (CDs), which were introduced by Green (1989) to describe, compare and control how programming language features affect program design strategies. The dimension role-expressiveness, for example, relates to how well a piece of program code (e.g., "+") reveals its meaning without a need to study the context

of the piece (addition, string catenation, etc.). Later, CDs were developed further and applied to many types of cognitive artifacts, such as educational theorem provers (Kadoda, Stone, & Diaper, 1999), prototyping techniques (Dearden, Siddiqi, & Naghsh, 2003), and music notations (Blackwell & Green, 2003).

Even though the area of PoP seems to be quite narrow—computer programming—it covers a large variety of phenomena, from novices' problems to experts' tacit knowledge, from program design to testing and maintenance, and from short individual programs to huge software systems. Consequently, research methods vary as well. Most often, research methods have been adopted from cognitive psychology (e.g., controlled experiments run in laboratory settings) or social sciences (e.g., field studies with qualitative analysis techniques), but it seems that in many subareas appropriate research methods are yet to be discovered. As many researchers are also computer science educators, they have instant access to novices and, therefore, studies on novices' problems and programming education are frequent. A new source of research materials is provided by various open source communities that make their program code, change logs, and discussions among program developers freely available on the net. These materials represent expert programming in state-of-the-art contexts.

During the past two decades, two important workshop series have been fully devoted to PoP: the Workshop on Empirical Studies of Programmers (ESP), based primarily in the USA, and the Psychology of Programming Interest Group Workshop (PPIG), having a European character. The first ESP workshop was held in 1986 in Washington, DC, the eighth and last one in 1999. Later, this workshop series was incorporated into the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC), which, however, has a broader scope than pure PoP and includes implementation aspects and the like. The European conference series, PPIG, started in 1989, and continues to be organized annually. It is more informal in nature than ESP; in addition to fully developed research papers, PPIG proceedings include position papers and suggestions for individual studies. Many of the best papers have later been published in more formal conferences and journals.

The organization behind PPIG workshops, the Psychology of Programming Interest Group, was established in 1987 and—just like the workshop—is informal in nature. For instance, there is no formal committee: Decisions are discussed in an open business meeting held during every workshop. The interest group publishes an electronic newsletter and hosts two mailing lists, a low-volume announcements list plus another list for discussions. In essence, the interest group is an informal collection of people who are enthusiastic about psychological aspects of programming and software engineering<sup>1</sup>.

The latest PPIG workshop was held in Joensuu, Finland in July 2007. The scientific program consisted of four half- or full-day tutorials, a doctoral consortium, two keynote addresses, 18 technical presentations, and two discussion sessions. All paper submissions were reviewed by at least two—usually three—anonymous reviewers and papers were accepted in two categories: Full Papers and Work in Progress Reports, as decided by the Program Committee. This special issue of *Human Technology* contains five of those papers, selected based on the reviewers' statements. The papers were re-reviewed and improved for publication in this journal. These papers demonstrate the variability in themes and research methodologies of PPIG workshops.

The first two papers deal with research methodology. In the article “A Coding Scheme Development Methodology Using Grounded Theory for Qualitative Analysis of Pair Programming,” Stephan Salinger, Laura Plonka, and Lutz Prechelt consider the analysis of

rich video data that is typical for programming protocols. They have used grounded theory (Strauss & Corbin, 1990), in which the whole coding is based totally on protocol data, and developed a specific coding scheme to be used in the context of pair programming. The article provides guidance for the use of grounded theory in the analysis of rich protocol data when the purpose of a study is to understand cognitive phenomena within a design process. The principles described in the paper apply to domains outside programming, as well.

Rozilawati Razali, Colin Snook, Michael Poppleton, and Paul Garrat have used two methods to evaluate the usability of a semiformal notation that combines UML (Object Management Group, 2007) with B (Abrial, 1996), the latter being a formal notation for describing semantics. The evaluation methods include CDs and the results were analyzed using grounded theory. This paper, "Usability Assessment of a UML-based Formal Modeling Method Using a Cognitive Dimensions Framework," thus demonstrates how one can use several research methods for the usability analysis of tools within formal domains that involve design activities.

The next two papers concentrate on specific details within programming. Sue Jones and Gary Burnett tackle a popular problem: how to predict students' success in learning programming. Earlier work on this area has looked at correlation between programming success and some other property, for example, field dependence (e.g., Mancy & Reid, 2004), inclination to systematic behavior (e.g., Dehnadi, 2006), or self-efficacy (e.g., Wiedenbeck, LaBelle, & Kain, 2004). Jones and Burnett study spatial ability and find a positive correlation between mental rotation ability and programming success in their paper "Spatial Ability and Learning to Program."

Juha Sorva looks at variable-oriented programming paradigm (Sajaniemi & Niemeläinen, 1989) and combines it with the notion of roles of variables (Sajaniemi, 2002). This results in a data-flow description of programs that explicitly classifies variables using a fixed set of categories found in expert programmers' tacit knowledge (Sajaniemi & Navarro Prieto, 2005). The article, "A Roles-Based Approach to Variable-Oriented Programming," also demonstrates how the new notation can be used for mental exercises even without a fully functional implementation.

The final paper, "From Procedures to Objects: A Research Agenda for the Psychology of Object-Oriented Programming Education" by Jorma Sajaniemi and Marja Kuittinen, presents an overview of PoP research in novice education and debates whether existing research literature, which deals mostly with procedural programming, can be applied to current educational practice that is based on object-oriented programming (de Raadt, Watson, & Toleman, 2002). The authors point out fundamental differences that make the use of existing research results in the current context dubious and suggest areas that should be studied if programming education is to be based on research results rather than intuition.

The five papers included in this special issue of *Human Technology* represent studies in research methodology and in small scale programming. Programming in the large, that is, production of complex software systems, is not represented in this set. The reason is simple: There were very few papers on that area in the 2007 PPIG workshop. This is also typical for PoP research in general. Research into the construction of large systems, although highly important, is very expensive and industry partners willing to use their time for such research are hard to find.

There is still a long way to go before PoP can provide an extensive picture of programming and software engineering in general.

## ENDNOTE

1. For more information on the Psychology of Programming Interest Group, see <http://www.ppig.org>

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