# An Upcoming Study of Potential Success Factors for an Introductory Model-Driven Programming Course

Jens Bennedsen
IT University West
Fuglesangs Allé 20
DK-8210 Aarhus V
Denmark
jbb@it-vest.dk

Michael E. Caspersen
Department of Computer Science
University of Aarhus
Aabogade 34, DK-8200 Aarhus N
Denmark
mec@daimi.au.dk

## ABSTRACT
In order to improve the course design of an objects-first CS1 programming course we will study potential indicators of success for such a course.

The general interest for success factors for a programming course has been toward more knowledge-oriented factors like math score and previous programming experience. Unfortunately, improving these factors is out of our control. We therefore increase the factors to include the more general factors of motivation and power of abstraction as well as the “soft” elements of emotional health and social well-being — factors which to a certain extent is improvable within the introductory programming course.

In this paper, we explain and discuss the design of the research, including our understanding of the factors under study.

Because of the variety of interpretations of “objects-first”, the present research is necessary as a supplement to earlier research in order to make generalizable results on the success factors for objects-first programming.

## Keywords
Objects-first, CS1, object-oriented programming, model-driven programming, predictors of success, course design.

## 1. INTRODUCTION
A substantial amount of research has been conducted in order to identify variables that are predictors of success of students aiming for a university degree. Investigated variables encompass among other things gender [4,26], the educational level of parents [33] and ACT/SAT scores [4,14,28]. These factors represent scientific competences (math score for example) or unbiased factors (e.g. gender). However, these variables do not account for all of the variation in academic success. Szulecka, Springett, and de Pauw [32] have suggested that the major causes of attrition among first-year college students are emotional rather than academic factors. Furthermore, Leafgran [18] claims that emotional health has a positive influence on the students’ success in college.

Research has been conducted both in the general context of education, within computer science, and in the more topic specific area of introductory programming [4,5,9,19]. Even in the area of introductory object-oriented programming there has been research trying to establish general factors to predict success or failure of particular students. Especially the work of Phil Ventura [35] focus on a systematic evaluation of hypothesis related to the factors for success of an introductory programming course using an objects-first approach [17]. The results are documented in [35, 36].

As always, there are some preconditions to the research. One important precondition is the characteristics of the course that founds the basis of the research. Ventura used a CS1 course with a graphics early approach [36 p. 241]. In our research, we look for potential success factors for an introductory programming using a different approach than Ventura’s, a so-called model-based approach to programming [3]. Both courses are objects-first.

## 2. THE COURSE
The students in this research all follow an introductory programming course at the University of Aarhus. The course constitutes the first half of CS1. The course runs for seven weeks. One to two weeks after the course there is a lab test with a binary pass/fail grading. Every week there are four lecture hours, two lab hours and two class hours with a teaching assistant (TA). Besides scheduled hours, the students are supposed to work approximately seven hours per week in study groups or on their own.

There are roughly 300 students from a variety of study programmes, e.g. computer science, mathematics, geology, nano science, economy, multimedia, etc. 40 % are majors in computer science, and they are the only group of students that continue with the second half of CS1. The rest of the students proceed to other programming courses related to their fields (e.g. multimedia programming, scientific computing, etc.).

The students are grouped in teams of 18-20 students; in the fall of 2005, there are 14 such teams. Each team has its own TA.

The goal is that the student learns the foundation for systematic construction of simple programs and through this obtains knowledge about the role of conceptual modelling in object-oriented programming. Furthermore, it is the goal that the student becomes familiar with a modern programming language, fundamental programming language concepts, and selected class libraries.

The two lab hours per week are used for pair programming where the students solve a practical programming exercise.

The two class hours per week are used for discussion of a weekly assignment, for discussion of other exercises that the students has been working on, as well as for discussion of topics from the textbook and lecture notes.

The course content is fundamental programming language concepts, object-orientation, and techniques for systematic construction of simple programs. For further details on the structure and contents of the course, see [3,13].

The exam takes place in a lab. Each group of 20 students get a different assignment. In principle, the assignments are identical. For a more thorough description of the exam, see [4].

# 3. RESEARCH METHOD

In this paragraph, we discuss the methodology utilized in identifying the predictors of success for the CS 1 course described in the previous section. Section 3.1 outlines some of the research questions. Section 3.2 provides details on the subjects involved in the study. Section 3.3 describes the data and how it was provided, while Section 3.4 presents and discusses the hypothesis.

## 3.1 Research Questions

We look for potential success indicators that are statistically significant in predicting students' success when undertaking a model-driven introductory programming course. The factors are motivated by previous research in the field [16][19][35][37][38] as well as in the more general field of education [24]. The specific research questions are:

1. What is the correlation of abstraction power to model based CS1?
2. What is the relationship of emotional health to model-based CS1?

## 3.2 Subjects

The subjects studied in this research will be students enrolled at the course Introduction to Programming at the University of Aarhus during fall of 2005. Only data from students taking the course for the first time were used; to exclude the possibility of an extended practice effect, we decided to exclude from our investigations the students who followed the course more than once. In order to investigate the effect of some factors, we will look for correlations with the next courses that the students follow.

## 3.3 Data

Several different data sources will be used in this study. Information comes from the administrative system at the university (gender, enrolment date, major), the course web site (team number), the TAs (the students diligence during the course), the final exam (the score in the exam), an experiment conducted by the authors (their abstraction power) and a questionnaire (there social and emotional health, prior programming experience, motivation).

**Success**. The final exam is a practical, programming test. The official result of the exam is a binary grading (pass or fail). In order for this research to be able to analyse the results at a finer grain, one author will post-mark all the students' solutions. The result of the more fine-grained marking is a ten-ary grading on the scale (0, 3, 5, 6, 7, 8, 9, 10, 11, and 13) (see [12]).

In order to pass an exam, a student needs a grade of 6 or more. To validate the results of the post-marking, the post-marking is compared to the official results of the exam in the sense that all the students who passed the exam got a grade of 6 or more and the students who failed the exam got a grade of 5 or less. In order to ensure that the marking was fair, the co-author will mark thirty randomly selected answers.

In all the statistical tests, the result of the marking is used as the indicator of success — higher grade means more success.

## 3.4 The hypotheses

In the following, we will discuss the research questions.

### *3.4.1 Abstraction power*

Many educators within the computer science field argues that abstraction is a core competence – see e.g. [2,22,23]. However, no one has defined what is meant by abstraction. In this research, we use the definition and test defined by Shayer and Adey [1][30]. Based on Piaget's work on the nature of knowledge they define eight stages of cognitive development of pupils ([1] p. 30):

| | |
|---|---|
| 1 | Pre-operational |
| 2A | Early concrete |
| 2A/2B | Mid concrete |
| 2B | Late concrete |
| 2B* | Concrete generalization |
| 3A | Early formal |
| 3A/3B | Mature formal |
| 3B | Formal generalization |

**Table 1: Cognitive development stages**

Shayer and Adey use it in the age range of 5 to 16 year old pupils. We use the stages on students in the range of 18 to 22. Shayer and Adey found that at the age of 16 30 percent of the pupils were at stage 3A and only approximately 10 percent at stage 3B. Further more they found that the curve describing the progression of stages was very flat at that age [10]. We therefore believe it will be relevant to use this stage model to describe the students cognitive development stage and thereby their abstraction power.

Based on Inhelder and Piaget [17], Adley and Shayer describe what they call "reasoning patterns of formal operations" and group the eight patterns in three groups: Handling of variables, relationships between variables and formal methods. See [1] pp. 17-25 for a more exhaustive description. A person can of course be at a higher development stage in one of these reasoning patterns, but "one would not find an individual competently fluent with one or two of the reasoning patterns who would not, with very little experience, become fluent with them all" ([1] p. 17).

Shayer and Adley have developed several tests to determine the students' cognitive stage. These test focus on several of the reasoning patterns, but since the students "with very little experience, become fluent with them all" we find it sufficient to use only one test. We will use the so called "pendulum" test; a test that has been used for a long time to test children's understanding of the laws of the physical world [6]. Shayer and Adey argues that the pendulum test is particular focused on testing the cognitive development stages from 2B to 3B ([1] p. 30) – the span of cognitive stages we find relevant to test for our age group.

### *3.4.2 Emotional health*

Many psychological variables affect the success and retention of students in an educational setting. Brooks and DuBois [8] found that emotional variables have a strong influence on how well students adjusted to their first year at college. This is a strong predictor of academic success [34].

High self-confidence [7], self-control [39], and having an achievement-oriented personality [14] are associated with a higher academic performance. In addition, students who are adaptive perfectionists tend to adjust better to college and as a result, have higher rates of retention [25].

We will investigate the impact of these factors have an on the success of a model-based introductory programming course.

Perfectionism is assessed using a subscale of the Eating Disorders Inventory [15]. Students will respond to statements about their performance levels in activities and the influence of the expectations of others (e.g., family, teachers, parents), such as, "Only outstanding performance is good enough in my family." Responses indicated the participant's agreement based on a 6-point scale ranging from 1 (never) to 6 (always) and were summed.

Self-Esteem is measured using the Rosenberg Self-Esteem Scale [27]. This scale is probably the most widely used scale measuring self-esteem. It has ten questions addressing personal feelings about one-self plus positive and negative emotions (e.g., "I feel I have a number of good qualities"). Students responded on a 4-point scale ranging from "strongly agree" to "strongly disagree".

Coping tactics is measured via the Brief COPE [11]. This 28-item Likert-type questionnaire contains 14 tactics (e.g., seeking emotional support, giving up, etc.). Students responded to how they would deal with a stressful event on a 4-point scale ranging from "I wouldn't do this at all" to "I would do this a lot". This measure has been tested on a variety of populations, and the measure has been validated and shown to be reliable [11].

Affective states is measured using the 30-item version of the Profile of Mood States (POMS) [20]. This Likert-type questionnaire assesses the mood states of tension, depression, anger, vigour, fatigue and confusion. This measure has also been tested on several populations and has shown to be reliable and valid [31].

Optimism is assessed via the Defensive Pessimism Scale (DPS) [21]. The students will indicate the degree to which each of 11 statements describing characteristics of either optimism or pessimism is representative of their thoughts and behaviour in academic situations. Previous studies utilizing this questionnaire have found this scale to have good predictive utility [29].

## 4. CONCLUSIONS

Several studies of success factors within computer science have been undertaken. However, all of these studies have focused on what we call traditional indicators and not on what in other areas have been found to have the greatest impact on success (emotional factors) nor on what many educators believe to be one of the most important skills of a programmers (abstraction power).

In this article, we have outlined how we will address and investigate the influence of these two factors.

Further work need to be done in order to make generalizable results on the success factors for objects-first programming; we investigate potential indicators of success that we believe to be dominant in predicting success and which we can do something about by changing our course design.

## 5. ACKNOWLEDGEMENT

It is a pleasure to acknowledge Jens Holbech for his help regarding measurement of abstraction power.

## 6. REFERENCES

[1] Adey, P and Shayer, M. 1994. Really raising standards: cognitive intervention and academic achievement. Routledge. London, England

[2] Alphonce, C. and Ventura, P. 2002. Object orientation in CS1-CS2 by design. In Proceedings of the 7th Annual Conference on innovation and Technology in Computer Science Education (Aarhus, Denmark, June 24 - 28, 2002). ITiCSE '02. ACM Press, New York, NY, 70-74

[3] Bennedsen, J. & Caspersen, M.E. (2004). Programming in Context – A Model-First Approach to CS1, Proceedings of the thirty-fifth SIGCSE Technical Symposium on Computer Science Education, Norfolk, Virginia, 2004, pp. 477-481.

[4] Bennedsen, J & Caspersen, M. E. (2005). An Investigation of Potential Success Factors for an Introductory Model-Driven Programming Course. Proceedings of ICER 2005 The First International Computing Education Research Workshop, October 1-2, 2005, Seattle, WA, USA

[5] Bergin, S & Reilly, R (2005) Programming: factors that influence success. SIGCSE '05: Proceedings of the 36th SIGCSE technical symposium on Computer science education, St. Louis, Missouri, USA. pp. 411-415.

[6] Bond, T. B. (2004). Piaget and the Pendulum. Science and Education, 13, pp. 389 - 399

[7] Boyer, S. P., & Sedlacek, W. E. (1988). Noncognitive predictors of academic success for international students: A longitudinal study. Journal of College Student Development, 29, 218-223.

[8] Brooks, J. H., & DuBois, D. L. (1995). Individual and environmental predictors of adjustment during the first year of college. Journal of College Student Development, 36, pp. 347-360.

[9] Byrne, P., & Lyons, G. (2001). The effect of student attributes on success in programming. Proceedings of the 6th annual conference on Innovation and technology in computer science education, 49-52.

[10] Capon, N., and Kuhn, D., (1979) Logical Reasoning in the Supermarket: Adult Females' Use of a Proportional Reasoning Strategy in an Everyday Context," Developmental Psychology, 15 (July 1979), pp. 450-452

[11] Carver, C. S. (1997). You want to measure coping, but your protocol's too long: Consider the brief COPE. International Journal of Behavioural Medicine, 4, 92-100.

[12] Exam score (2005). http://www.retsinfo.dk/_GETDOCM_/ACCN/B19950051305-REGL (English translation can be found in the bottom) Last accessed April 30 2005.

[13] Fjuk, A., Berge, O., Bennedsen, J. & Caspersen, M. (2004). Learning Object-Orientation through ICT-mediated Apprenticeship. Procedings of the 4th IEEE International Conference on Advanced Learning Technologies, Joensuu, Finland.

[14] Foster, T. R. (1998). A comparative study of the study skills, self-concept, academic achievement and adjustment to college of freshman intercollegiate athletes and nonathletes.

Dissertation Abstracts International Section A: Humanities and Social Sciences, 58(12-A), pp. 4565.

[15] Garner, D. M., Olmstead, M. P., & Polivy, J. (1983). Development and validation of a multidimensional eating disorder inventory for anorexia nervosa and bulimia. International Journal of Eating Disorders, 2, p. 15-34.

[16] Hagan, D., & Markham, S. (2000). Does it help to have some programming experience before beginning a computing degree program? ACM SIGCSE Bulletin, 5th annual SIGCSE/SIGCUE conference on Innovation and technology in computer science education, 32(3). pp. 25-28.

[17] Inhelder, B. & Piaget, J. (1958). The Growth of Logical Thinking .Routledge & Kegan Poul. London, England

[18] Leafgran, F. A. (1989). Health and wellness programs. In M. L. Upcraft & J. N. Gardner (Eds.), The freshman year experience (pp. 156-167). San Francisco: Jossey-Bass.

[19] Leeper, R. R., & Silver, J. L. (1982). Predicting success in a first programming course. Technical Symposium on Computer Science Education, Proceedings of the thirteenth SIGCSE technical symposium on Computer science education, Indianapolis, Indiana, United States. pp: 147 – 150.

[20] McNair, D. M., Lorr, M., & Droppleman, L. F. (1981). Manual for the Profile of Mood State. San Diego: Educational and industrial Testing Service.

[21] Norem, J. K., & Cantor, N. (1986). Defensive pessimism: Harnessing anxiety as motivation. Journal of Personality and Social Psychology, 51, 1280-1217.

[22] Nguyen, D. & Wong, S. (2001) OOP in Introductory CS: Better Students Through Abstraction Position paper for OOPSLA 2001, Fifth Workshop on Pedagogies and Tools for Assimilating Object-Oriented Concepts

[23] Or-Bach, R. and Lavy, I. 2004. Cognitive activities of abstraction in object orientation: an empirical study. SIGCSE Bull. 36, 2 (Jun. 2004), 82-86.

[24] Pritchard, M. E. & Wilson G S. (2003). Using Emotional and Social Factors to Predict Student Success, Journal of College Student Development, Vol. 44(1).

[25] Rice, K. G., & Mirzadeh, S. A. (2000). Perfectionism, attachment, and adjustment. Journal of Counselling Psychology, 47, 238-250.

[26] Rountree, N. Rountree, J. and Robins, A (2002).Predictors of success and failure in a CS1 course. SIGCSE Bulletin, vol. 34(4) pp. 121—124.

[27] Rosenberg, M. (1965). Society and the adolescent selfimage. Princeton, NJ: Princeton University Press.

[28] Sanders, R. T., Jr. (1998). Intellectual and psychosocial predictors of success in the college transition: A multiethnic study of freshman students on a predominantly White campus. Dissertation Abstracts International Section B: The Sciences and Engineering, 58(10-B), pp. 5655.

[29] Sanna, L. J. (1998). Defensive pessimism and optimism: The bittersweet influence of mood on performance and prefactual and counterfactual thinking. Cognition and Emotion, 12, 635-665.

[30] Shayer, M. and Adey, P (1981). Towards a Science of Science Teaching. Heinemann Educational Publishers, Oxford, England

[31] Shin, Y., & Colling, K. B. (2000). Cultural verification and application of the Profile of Mood States (POMS) with Korean elders. Western Journal of Nursing Research, 22, p. 68-83.

[32] Szulecka, T. K., Springett, N. R., & de Pauw, K. W. (1987). General health, psychiatric vulnerability and withdrawal from university in first-year undergraduates. British Journal of Guidance & Counselling Special Issue: Counselling and health, 15, pp. 82-91.

[33] Ting, S. R., & Robinson, T. L. (1998). First-year academic success: A prediction combining cognitive and psychosocial variables for Caucasian and African American students. Journal of College Student Development, 39, pp. 599-610.

[34] Van Heyningen, J. J. (1997). Academic achievement in college students: What factors predict success? Dissertation Abstracts International Section A: Humanities & Social Sciences, 58(6-A), 2076.

[35] Ventura, P. R. (2003). On the Origins of Programmers: Identifying Predictors of Success for an Objects First CS1", PhD. dissertation, The State University of New York at Buffalo, 2003.

[36] Ventura, P. R. & Ramamurthy, B. (2004). Wanted: CS1 Students. No Experience Required. ACM SIGCSE Bulletin, Proceedings of the 35th SIGCSE technical symposium on Computer science education, Vol. 36(1) pp. 240 – 244.

[37] Wilson, B. C., & Shrock, S. (2001). Contributing to success in an introductory computer science course: A study of twelve factors. ACM SIGCSE Bulletin , Proceedings of the thirty second SIGCSE technical symposium on Computer Science Education, 33(1), pp. 184-188

[38] Wilson, B.C. (2002). A Study of Factors Promoting Success in Computer Science Including Gender Differences. Journal of Computer Science Education 12 (1-2), pp. 141 – 164

[39] Wolfe, R. N., & Johnson, S. D. (1995). Personality as a predictor of college performance. Educational & Psychological Measurement, 55, 177-185.