ABSTRACT
Learning to program is notoriously difficult. In order to understand predictors of success and, when possible, improve the course design of the introductory programming course to increase the likelihood of success, we study a number of factors that potentially indicate programming aptitude.

We have studied the influence of emotional and social factors on students’ learning outcome. Emotional health and social well-being has been measured in terms of five variables: perfectionism, self-esteem, coping tactics, affective states, and optimism. No correlation was found!

Others have found the variables perfectionism, self-esteem, and affective states to be predictors of success. We identify potential explanations for this seeming contradiction.

Categories and Subject Descriptors
K.3.2 [Computers & Education]: Computer and Information Science Education – computer science education, information systems education.

General Terms
Experimentation, Human Factors.

Keywords
Computer science, mathematics, introductory courses, predictors of success.

1. INTRODUCTION
Learning to program is notoriously difficult. For almost forty years teaching programming to novices has been considered a big challenge and it still is [9, 12, 15, 24, 30, 34]; in fact it is considered one of seven grand challenges in computing education [16].

1.1 Improving Learning Through Predictors of Success
We can do several things to (try to) improve the state of affairs. We can improve what we teach (contents), how we teach (pedagogical design), or the learning conditions of the students. Himm and Hippe [13] has developed a didactical model where they identify six aspects that influence students’ learning outcome:

1. Student learning premises – knowledge, experiences, attitudes and skills that the students already possess when they come for the first lesson of the course.
2. External conditions – conditions that limit or make learning possible such as equipment, artefacts, time, place, classroom settings, teacher’s resources, learning resources, etc.
3. Objectives for the learning activity – what the students should learn from the course/activity in terms of knowledge, skills, attitudes, and competencies.
4. Contents – what the course is about, how content is selected, adjusted and presented.
5. Learning process – the process of change within the learning subjects (the students), and reflections on how the intended changes are facilitated.
6. Evaluation – assessment or evaluation in relation to the teaching process, in relation to the objectives for the course and in relation to the students’ learning (pp. 28-30).

Three of these aspects are concerned with what we teach (3, 4, and 6), one is concerned with how we teach (5), and one is concerned with the student’s learning conditions (1).

To help focus our resources, we look for factors that are predictors of success; in particular we are interested in improvable factors of the students’ learning premises. In this research we study the influence of emotional and social factors on students’ learning outcome. If these factors turn out to be predictors of success, we will focus resources on identifying ways to improve the students’ emotional and social well-being at the university.

1.2 Related Work on Predictors of Success
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 – variables that account for parts of the students’ learning premises. Investigated variables encompass among other things gender [2, 26, 36], the educational level of parents [33], ACT/SAT scores [1, 2, 4, 27], performance in prior courses [7] and abstraction ability [1, 31]. All of the above studies have focused on (academic) knowledge, but the results are not conclusive and point in different directions (e.g. [36] concludes that math is not a predictor of success for an introductory object-oriented programming course while [2] concludes the opposite). The general pattern is a rather weak (if any) impact of the analysed variables; it is not the case that they all (or at least a major part of them) verify an impact of the same type of variable. In general the studies show that gender and abstraction ability has no influence, previous math score have an impact in some cases but not in others, and scores in
Mouw and Khanna [18] conclude from a review of 39 studies that only 5% to 25% of the variance in college performance can be accounted for by aptitude scores such as ACT and SAT. The lack of clear and definite conclusions has caused researchers to study the impact of other types of factors. Szulecka, Springett, and de Pauw [32] have suggested that the major causes of attrition among first-year college students are due to emotional rather than academic factors. This is consistent with the conclusions of Pascarella and Terenzini from a comprehensive literature review: “Thus, as a measure of successful adaptation to an academic environment, grades tend to reflect not only requisite intellectual skills but also desirable personal work habits and attitudes” [20] (p. 388).

Many psychological variables affect the success and retention of students in an educational setting. Brooks and DuBois [3] 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 [35]. Furthermore, Leafgran [14] claims that emotional health has a positive influence on the students’ success in college. Pritchard [21] concludes that social factors have a positive influence on student performance. High self-confidence, self-control, and having a conscientiousness-oriented personality [37, 38] 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 [23].

2. STUDENTS AND STUDY PROGRAMS

The students in this research are freshmen in computer science and mathematics at the University of Aarhus in the academic year 2005-2006.

We investigate the correlation between emotional health and social well-being on the one hand and the success in selected first year courses in computer science or math on the other.

The general structure of an academic year at the Faculty of Science at the University of Aarhus is four quarters (of seven weeks) each followed by a 2-4 week examination period. There are three courses (of 5 ECTS) in each quarter.

The first year program in computer science and math is presented in Table 1 and Table 2 respectively.

<table>
<thead>
<tr>
<th>4. Algorithms &amp; Data Structures 2</th>
<th>Programming Languages</th>
<th>Regularity &amp; Automata</th>
</tr>
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<tbody>
<tr>
<td>3. Algorithms &amp; Data Structures 1</td>
<td>Web Technology</td>
<td>Computer Architecture</td>
</tr>
<tr>
<td>2. Programming 2</td>
<td>Usability</td>
<td>Calculus 2</td>
</tr>
<tr>
<td>1. Introduction to Programming</td>
<td>Perspectives on CS</td>
<td>Calculus 1</td>
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</table>

Table 1: First year program in computer science

<table>
<thead>
<tr>
<th>4. Mathematical Modeling 2</th>
<th>Mathematical Analysis 2</th>
<th>Linear Algebra</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Mathematical Modeling 1</td>
<td>Mathematical Analysis 1</td>
<td>Calculus 2</td>
</tr>
<tr>
<td>2. Introduction to Programming</td>
<td>Perspectives on Mathematics</td>
<td>Calculus 1</td>
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<tr>
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<td>Perspectives on CS</td>
<td>Calculus 1</td>
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</tbody>
</table>

Table 2: First year program in mathematics

The courses in italics are those with a grading scheme fine-grained enough to be used in this research. Only ten students participated in the exam of the course Programming Languages, so this course is excluded from the analysis.

3. RESEARCH METHOD

In this paragraph, we discuss the methodology utilized in identifying predictors of success for the courses described in the previous section. Section 3.1 outlines the research questions. Section 3.2 describes the data and how they were provided. Section 3.3 provides details on the subjects involved in the study. In section 3.4 we present and discuss the hypothesis while section 3.5 is a presentation of the statistical analysis.

3.1 Research Questions

In this research we study the influence of emotional and social factors on a student’s learning outcome; our hypothesis is that there is a positive correlation between social well-being and emotional health and how well students perform in introductory courses at university. The specific research question is:

What is the relationship of social well-being and emotional health to students’ success in introductory computer science and math?

3.2 Data

Two data sources will be used in this study. Information comes from the administrative system at the university (the score in the exams) and a questionnaire with questions about social well-being and emotional health, motivation, etc.

The result of the final exam is used as an indicator for success – higher grade, more success. Two grading scales are used: pass/fail and a ten-ary scale (see [10]). Courses with a binary grading (pass/fail) are not fine-grained enough; we therefore only consider courses using the ten-ary scale.

3.3 Subjects

134 computer science students participated in one or more of the exams (Table 1). 62 math students participated in one or more of the exams (Table 2).

206 students voluntarily answered the questionnaire (some from other study programs), 77 of them have participated in one or more of the computer science exams; 50 have participated in one or more of the math exams.

3.4 The hypothesis

As our research question reflects, we focus our attention on two non-academic factors: emotional health and social well-being. We use five variables to measure students’ emotional health and social well-being: perfectionism (PERFECT), self-esteem (SELFEST), coping tactics (COPE), affective states (POM), and optimism (OPTIMISM). The choice of factors are motivated by many studies in general educational research [22].

In the field of (educational) psychology several tests have been produced and validated. In our study we will use a battery of such tests and evaluate the correlation with the exam results.

Perfectionism is assessed using a subscale of the Eating Disorders Inventory [11]. 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 indicate the participant’s agreement based on a 6-point scale ranging from 1 (never) to 6 (always).

Self-esteem is measured using the Rosenberg Self-Esteem Scale [25]. This scale is probably the most widely used scale measuring self-esteem. It has ten questions addressing personal feel-
ings 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 [5]. 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 [5].

Affective states is measured using the 30-item version of the Profile of Mood States (POMS) [17]. This Likert-type questionnaire assesses the mood states of tension, depression, anger, vigour, fatigue and confusion. This measure has been tested on several populations and has shown to be reliable and valid [29].

Optimism is assessed via the Defensive Pessimism Scale (DPS) [19]. 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 [28].

### 3.5 Statistical Analysis

The goal is to find how much impact (if any) the five variables have on the result of the examination. One way to obtain this is to use a multiple regression analysis based on an as simple as possible model using the variables in question and the relevant interaction variables (i.e. combination of the variables).

We end up with a linear regression model describing the functional relationship between a predicted variable (exam score) and a set of predictor variables. The linear regression model has the form: $\hat{y} = \alpha + \beta_1 x_1 + ... + \beta_n x_n$, where $\hat{y}$ is the predicted variable, $\alpha$ is a constant displacement, and each $x_i$ is a predictor variable with corresponding coefficient $\beta_i$.

In order to use the multiple regression model, five prerequisites need to be fulfilled: Linearity; Normal distribution; Homoscedasticity (the conditional distribution has constant standard deviation throughout the range of values of the explanatory variables); No collinearity (two or more variables have a strong linear relationship (i.e. explains the same)); No problematic outliers (an observation falls far from the rest of the data and the mean is highly influenced). A scatter-plot of the data justifies that the requirements are met.

The linear regression analysis is done by starting with a model consisting of all five predictor variables and then iteratively removing a predictor variable that is not statistically significant at the 5% significant level (in the case of more than one, we remove the one that is least statistically significant).

The analysis of the data is performed in Microsoft Excel using the add-in for “data analysis”.

### 4. RESULTS

This section describes the results of the statistical analysis for computer science and math respectively.

#### 4.1 Computer Science

In general the correlation between the five predictor variables and the outcome of the exams depends at most on one variable using a 5% confidence interval.

For the course Programming 2 no variables correlate with the students’ exam score; the course is therefore excluded from Table 3.

#### Table 3: Predictor variables for courses

| Course                  | Correlated variable | p-value | n   | Correlation
<table>
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<tr>
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<tbody>
<tr>
<td>Useability</td>
<td>COPE</td>
<td>5.2%</td>
<td>71</td>
<td>0.233</td>
</tr>
<tr>
<td>Calculus 2</td>
<td>OPTIMISM</td>
<td>0.9%</td>
<td>64</td>
<td>0.325</td>
</tr>
<tr>
<td>Computer Architecture</td>
<td>OPTIMISM</td>
<td>3.5%</td>
<td>57</td>
<td>0.315</td>
</tr>
<tr>
<td>Regularity &amp; Automata</td>
<td>OPTIMISM</td>
<td>1.9%</td>
<td>47</td>
<td>0.342</td>
</tr>
</tbody>
</table>

The exclusion of PERFECT, SELFEST and POM from Table 3 indicate that these variables do not predict success in any of the courses. COPE predicts only one course, and that is even only a weak prediction since the p-value is just above 5%.

The variable that predicts the best is OPTIMISM; but even the strongest prediction is weak: the correlation (Pearson correlation coefficient, r) between Regularity & Automata and OPTIMISM is only 0.342 (0.5 is traditionally considered to be the threshold value for correlation when considering only one variable). The correlation between OPTIMISM and exam score in Regularity & Automata is illustrated in Figure 1.

The correlation between OPTIMISM and Regularity & Automata can be raised using a logarithmic regression; the correlation coefficient is raised to 0.396 (Figure 1). The other courses do not show the same logarithmic correlation.

![Figure 1: Scatter plot of “Regularity & Automata” and OPTIMISM (dashed line = logarithmic trendline)](image)

#### 4.2 Math

For each course in the math program, the size of our population is considerably smaller than for the computer science program (between 25 and 31). According to [6] (p.108) a rule of thumb says that 10 observations per variable is a prerequisite for a multiple variable linear regression analysis. Consequently we have checked for correlations between the five variables independently (i.e. using a Pearson correlation test).

The results of the Pearson correlation tests show that none of the variables have a correlation with the result of the exam (using a threshold of 0.3). The closest r is -0.289 between POM and Calculus 2 (the negative sign indicates that students with a more positive affective state perform worse!).

### 5. DISCUSSION

We expected to find a positive correlation between social well-being and emotional health and how well students perform in
introductory computer science and math courses at university. We did not find a correlation, and that of course is a surprise; particularly because others have found PERFECT, SELFEST, and POM to be predictors of success.

We are not ready to abandon our hypothesis and therefore it is relevant to identify models that can explain our observations and the lack of confirmation of the hypothesis.

Verification of knowledge is traditionally discussed in terms of validity, reliability, and generalisability.

- **Validity** – the accuracy of research findings (do the variables measure what we claim)
- **Reliability** – consistency of research findings (will replicated measuring give the same result)
- **Generalisability** – are the results transferable to new contexts

Our discussion of potential explanation models is structured along these three terms.

### 5.1 Validity

The test instruments we have used are perhaps less suitable for Danish students due to cultural differences between Denmark (DK) and US where the instruments were designed and validated. Quite a few of the students responded negatively to the questionnaire and mentioned that they found many questions to be “odd” and “out of place”.

### 5.2 Reliability

At least one of our students responded that she found it difficult to indicate the representativeness of a statement like “I feel I must perform to perfection and if I can’t, I rather don’t perform at all” without a definition of the intended situation. The statement may be more true in the context of the test person’s family, and less true in the context of friends, or vice versa. In either case, the question is ambiguous, and that made some students uncomfortable about the the questionnaire as a reliable test instrument.

We have no reason to question the general reliability of the test instruments, but in retrospect we could have been more precise in our formulations when translating from English to Danish. In particular we could have been more specific about the intended situations to consider when answering questions about emotional feelings.

### 5.3 Generalisability

Our findings do not confirm previous findings but that does not allow us to conclude a contradiction with earlier findings. That conclusion is only valid if we can generalise previous findings to our context (or vice versa) which we cannot. A number of circumstances are sufficiently different that a generalisation is not immediately possible.

Fresmen at Danish universities are generally a couple of years older than freshmen at US colleges. The difference in age is likely to imply a difference in maturity and degree of dependency of parents which may be reflected in the way students respond to the questionnaire.

In DK university education is free; furthermore, students receive financial support from the state. In US parents typically pay a tuition fee of, say, 30-40,000 USD per year in college and support their kids financially as well. The resulting stronger dependency between US students and their parents may cause US students to feel a stronger pressure from their parents regardless of whether the pressure is real or not.

The culture in DK is different from the culture in US. DK is a land of homogeneity and equality much more than US. In DK it is considered important that everyone has equal rights and opportunities regardless of social background. Also, it is considered inappropriate if someone stands too much out from the crowd (there is a prevailing who-do-you-think-you-are attitude often caricatured in Danish literature); in US this character of personality seems to be encouraged and highly appreciated.

These cultural differences make it questionable whether it is possible to generalise US findings to a Danish context (and vice versa); consequently, we cannot conclude a contradiction with earlier findings.

If the above speculations carry some truth it is necessary to apply a different test instrument, more suitable to the Danish context, in order to properly test our hypothesis of positive correlation between social well-being and emotional health and students performance in introductory courses at university.

### 6. CONCLUSIONS

To help focus our teaching resources we have been looking for factors that are predictors of success and which can help improve the students’ learning premises.

We have studied the influence of emotional and social factors on students’ learning outcome. We have measured the factors in terms of five variables: perfectionism, selfesteem, coping tactics, affective states, and optimism.

No correlation was found; the variable that predicts the best is optimism with respect to a course on Regularity & Automata, but even that prediction is weak: the pearson correlation coefficient is only 0.342 (0.5 is considered to be the threshold value for correlation).

Others have found the variables perfectionism, selfesteem, and affective states to be predictors of success; in terms of validity, reliability, and generalisability we have identified potential explanations for this seeming contradiction.

### 7. FUTURE WORK

It is a noble goal to identify factors that are predictors of success and which may help improve students’ learning premises.

Dehadni & Bornat [8] has conducted an initial study which suggests that success in the first stage of an introductory programming course is predictable by noting consistency in use of the mental models which students apply to a basic programming problem even before they have had any contact with programming notation. We are currently verifying the findings of Bornat & Dehadni to see if we can confirm their result.

### 8. REFERENCES


