Motivational dynamics in basic needs profiles

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Motivational dynamics in basic needs profiles: Toward a person-centered motivation approach in engineering education

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Abstract

Background: While educators strive for optimal student motivation to enhance the quality of learning for all, different students attending the same course can have different needs. Person-centered approaches on basic needs profiles, categorizing individuals into groups with similar motivational profiles, have the potential to inform the relationship between different variables per cluster and to support instructional design sensitive to student differences. However, they are still absent in engineering education research (EER).

Purpose/Hypothesis: This gap is addressed by analyzing the basic psychological needs of engineering students as potential mediators during a mandatory, first-year course on the ethics and history of technology. The aims are thus to (1) determine whether distinct basic needs profiles can be identified and (2) investigate how students’ motivation differed and evolved during the course for the different basic needs profiles.

Design/Methods: Two-step cluster analyses, MANOVA, and t-test analyses were conducted using the data collected from 1864 students with digital questionnaires completed at three points within a semester of a course.

Results: We construed four student profiles from the survey data based on the distinct roles of competence and autonomy, with post hoc tests showing relationships between meaningful differences in evaluation of course elements, motivation, course appreciations, and motivation dynamics.

Conclusions: The person-centered approach is promising in engineering education design to answer differences in students’ basic needs to improve the quality of learning for all. We showed that the person-centered approach could also add important insights complementary to the variable-centered approach in EER on dynamics of motivation for learning.

KEYWORDS
basic need profiles, motivational dynamics, person-centered, self-determination theory

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**INTRODUCTION**

Individual needs of students that take the same course can differ due to differences in demographics, learning preferences, and personality, with the least motivated requiring more discrete support. For example, gender (Smith et al., 2013) and cultural background (Chubin et al., 2005; Isik et al., 2017; Soenens et al., 2015) have been shown to have an impact on individual needs and motivation. Four of the Big Five personality traits, extraversion, openness to experience, agreeableness, and conscientiousness, were also found to correlate positively with student motivation (Busato et al., 2000; Prentice et al., 2019). Felder and Brent (2005) mentioned three other categories of diversity that can have important implications for students’ needs during a course: learning preferences, approaches to learning, and attitudes about the nature of knowledge and how it should be acquired and evaluated.

Educators strive to optimize student motivation because motivation is key to learning (Baeten et al., 2010; G. J. T. Bombaerts et al., 2018), academic performance (Koh et al., 2010), persistence in engineering (Eris et al., 2010; French et al., 2005), and student and teacher well-being (Sheldon & Krieger, 2007; Shen et al., 2015, respectively). The numerous differences that influence students’ needs throughout a course make for a very complex set of variables, making it very difficult for teachers to tailor their courses to increase motivation. As a motivational model, self-determination theory (SDT) starts from a simple set of three basic needs: competence, autonomy, and relatedness (Ryan, 1995). Application of this pragmatic model in engineering education research (EER) may provide new insights into the basic needs of a particular student population and help augment motivation in general but most specifically in those students whose motivation level is low.

Recently, Vansteenkiste et al. (2020) and Vansteenkiste and Mouratidis (2016) have argued in educational psychology for a person-centered SDT approach relative to a variable-centered approach. Variable-centered approaches explain associations between variables. They are well suited for analyzing questions about the relative contributions that predictor variables make to an outcome. Person-centered approaches classify groups of individuals who share particular attributes or relations among attributes. They are appropriate for studying questions that concern group differences in patterns of development (Laursen & Hoff, 2006). They add diagnostic information as they bring together the background characteristics and needs of individuals. They promise to tailor interventions. And person-centered approaches also add theoretical evidence for the internal validity of theoretical concepts (Vansteenkiste et al., 2009). Knowledge about needs profiles of individual students may allow for more tailored interventions at different moments during the course.

Whereas motivation profiles have already been analyzed in EER (Smith et al., 2014; Vanasupa et al., 2010), an in-depth analysis of engineering students’ basic needs profiles is lacking. The outcomes may substantially aid the important and challenging goals to increase student motivation in this field of education.

In this article, we collect evidence on the basic needs profiles of engineering students in a mandatory first-year course on the ethics and history of technology (User-Society-Enterprise [USE] basic course). It is crucial to motivate engineering students’ learning in ethics and history courses to support their diverse future roles as responsible engineers (Colby & Sullivan, 2008; Hess et al., 2017; Rayne et al., 2006; Silvast et al., 2020; Turcanu et al., 2007; van Summeren et al., 2020). The USE basic course repeatedly yielded low course evaluation (item: “On a scale from 1–10, how would you rate this course?”) scores. It was decided to analyze motivational dynamics throughout the course to differentiate between personal factors (“Do students already show amotivation at the start of the course?”) and social factors (“Does the course demotivate motivated students?”) to increase understanding of how students’ motivation for learning can be improved.

To this end, we first investigated the nature of the basic needs of the students and tested whether particular needs profiles could be distinguished in the abovementioned USE basic course. Our second goal was to analyze motivation for learning and motivational dynamics throughout the course for students with different basic needs profiles.

**THEORETICAL BACKGROUND**

**2.1 Basic concepts of SDT**

We opted to use SDT as the theoretical framework for our investigations. As a motivational model, SDT has strong theoretical and empirical underpinnings and linkages to differences in both motivations at a certain moment in time (Vansteenkiste et al., 2009) and differences in dynamics of motivation during a certain time interval (Guay et al., 2000;...
2.1.1 | Personal and social factors

The interaction between personal factors (e.g., gender, personality, views on knowledge, learning preferences, expectations about the course) and social factors (e.g., the training course, social interactions) determines need-based experiences (Vansteenkiste et al., 2020). Course designers aim to design a course in a way students can optimize their basic needs.

2.1.2 | Basic needs

Ryan (1995) defines a basic human need as a psychological nutrient that is essential for individuals’ adjustment, integrity, and growth (refer to Vansteenkiste et al., 2020). SDT identifies three basic needs (Ryan & Deci, 2000a, 2000b): competence or the feeling of being able to successfully perform an activity, to balance being challenged and being in control of the outcome, and to experience mastery; autonomy, the feeling of psychological freedom and voluntary functioning, the feeling being supported to be able to make meaningful choices in an activity; and relatedness, denoting the need to be connected to others. SDT considers basic needs as inherent to human nature and essential to personal growth and motivation. It is important to support basic needs for course designers to foster student motivation.

2.1.3 | Motivation

SDT distinguishes five types of motivation on a self-determination continuum (Ryan & Deci, 2000a, 2000b), with amotivation being on the lower end of the spectrum, with people not feeling any intentionality for a task. Next on the spectrum is externally regulated motivation, where people perform an action to cope with internal pressures such as the need to do something to maintain self-worth. When people internalize a reason why they do something, SDT talks of introjected regulation. Finally, at the high end of the spectrum, we find intrinsic motivation. Here, people show interest in the activity itself prompted by a sense of personal interest and fulfillment. In SDT, external and introjected regulation are grouped as controlled motivation, while identified regulation and intrinsic motivation are grouped as autonomous motivation (Ryan & Deci, 2000a).
2.1.4 | Consequences

SDT describes a broad range of consequences of basic needs fulfillment and higher motivation, such as well-being (Ryan, 1995) or learning (Koh et al., 2010; Vanasupa et al., 2009). In education, consequences can be described with course outcomes like deep learning, grade point average (GPA), or students' course appreciation.

Whereas the origins of SDT can be traced back to the early 1970s (Deci, 1971), the first SDT-inspired publications in the field of EER did not appear until 2008. Since then, the role of the three basic needs competence, autonomy, and relatedness, and the different types of motivation proposed in SDT have featured in EER studies on learning and performance (Koh et al., 2010), learning environments (Lord et al., 2012), motivation of staff and teaching assistants (Kajfez & Matusovich, 2017), and course redesign (Kajfez & Matusovich, 2017; Vanasupa et al., 2010). K. Trenshaw et al. (2016) inquired into basic needs and found that autonomy was the least important out of the three psychological needs of SDT, although the course designer's primary goal was to support students' autonomy. They reported that team projects promoted relatedness; relatedness provided room for competence building, and when relatedness and competence were lacking, motivation declined. EER has used SDT's basic needs and motivation types to understand the redesign improvements of particular courses by comparing the results with a previous version or a control group, such as in simulation-based learning (Koh et al., 2010), work placements (Loke & Willmot, 2013), tutor feedback (G. Bombaerts & Nickel, 2017), and interdisciplinary study projects (Koch et al., 2017). Herman et al. (2013) used, as they call it, cost-efficient intrinsic motivation course conversions to create a course.

2.2 | Basic needs profiles

SDT mainly uses a variable-centered approach when analyzing relationships between variables. In recent research, a person-centered approach (Magnusson, 1998) was adopted to categorize individuals into groups whose members have similar basic needs profiles. A variable-centered approach will be interested in a list of variables and how they can be explained with analyses like correlation or regression research. A person-centered approach provides an additional perspective to the variable-centered approach, as the person-centered approach reflects the relationships between the different motivational constructs at the individual level. This is useful to tailor course redesign to the needs of specific groups of students. Analyses in both approaches start from different assumptions and different criteria. The person-centered approach has proven useful to better understand motivational differences and associated consequences in various fields. In sports (Cetinkalp & Lochbaum, 2018; Fernandez-Ozcorta et al., 2019; Kazak, 2018) and elderly care (Almagro et al., 2012; Souesme et al., 2016; Vanhove-Meriaux et al., 2018), two or three basic needs clusters were identified and dedicated recommendations made to improve coaching and care protocols. Analyzing secondary school students' relatedness to peers and teachers, Leon and Liew (2017) distinguished four clusters. The authors showed that the groups significantly differed in aspects of psychological well-being such as vitality, self-esteem, life satisfaction, and academic achievement. Amoura et al. (2015) evaluated two interpersonal styles of teaching (autonomy-supportive and controlling) and found four clusters in first-year psychology students for the two styles. The authors' basic needs cluster analysis added to the existing SDT research that autonomy-supportive and controlling styles of teaching are not opposite ends of a single continuum.

Within EER, and applying a research motivation scale with three subscales, that is, intrinsic reward, failure avoidance, and extrinsic reward, Smith et al. (2014) identified five clusters in their research on students' motivations toward scientific research or the implications of pursuing multiple research motivations simultaneously: an unmotivated, a neutral engagement, an emerging engagement, a high engagement group, and a group with high scores on the three subscales intrinsic reward, failure avoidance, and extrinsic reward. Dillon and Stolk (2014) revealed four profiles based on motivation for intrasemester longitudinal class surveys: one with moderate levels of both autonomous and controlled motivation, one with high levels of both, one dominated by extrinsic and amotivation characteristics, and one dominated by autonomous characteristics. To our knowledge, no studies on basic needs profiles are known in EER.

2.3 | Delineating motivational dynamics in different basic needs profiles

SDT studies how the interaction between personal and social factors can influence changes in motivation over time and regards motivation types as dynamic (R. J. Vallerand, 1997; R. Vallerand & Lalande, 2011). For example, Reis
et al. (2000) and Sheldon et al. (1996) found systematic day-of-the-week variations in emotional well-being and need satisfaction that underscored the need to consider traits and more variable determinants of well-being.

In EER, motivational variations are widely documented and often exploited in motivational prepost studies. The aim of these inquiries is to improve courses focusing, for example, on increasing engineering students' conceptual learning gains (Herman et al., 2017) or students' retention (Danowitz, 2016; K. F. Trenshaw et al., 2014). However, only a few EER studies have explicitly measured changes in motivation that occur during a course. Dillon and Stolk (2012, 2014) demonstrated intrasemester motivational fluctuations and the added value of weekly assessments in course groups. Prepost sampling showed no differences in start- and end-of-course motivation and suggested motivational stability. However, the weekly assessments identified two drops in motivation during the course and provided important information on motivational sensitivities at specific time points in the course.

Vanasupa et al. (2010) aimed at engaging engineering students in effective learning experiences and toward the long-term development needed for adaptive expertise. They delineated the students’ motivation during two different tracks of the same course. Students were given high autonomy in one track and performed a project with teachers who acted as clients. It was found that intrinsic motivation had increased during the course. Students worked with a real client in the second track, a multidisciplinary team of art and design, history, and engineering. Difficulties in team collaboration, a confusing mid-course design review, and end-of-course pressure had decreased intrinsic motivation. This information was used to redesign the course.

In a qualitative study with a narrative approach aimed at promoting the learning of class content, K. F. Trenshaw et al. (2014) monitored the role of individual choice, interpersonal relationships, and constructive failure in 200 students that attended a computer engineering course. They identified three motivational clusters. The first group reported a mixture of identified regulation and intrinsic motivation that shifted toward intrinsic motivation during the course. A second group started out with external and identified regulation and shifted toward identified regulation and intrinsic motivation. A third group reported amotivation and external regulation at baseline, experienced more severe amotivation during the course, and returned to baseline levels of amotivation and external regulation at course conclusion.

We aim to extend the research of Vanasupa et al. (2010) by analyzing different basic needs profiles in one course, while by providing a quantitative analysis of basic needs profiles we hope to add to K. F. Trenshaw et al.’s, 2014 and 2016 qualitative analysis. Although Dillon and Stolk (2014) applied more frequent (i.e., weekly) assessments, we aim to describe motivational differences across basic needs profiles. New insights into how motivation changes in different basic needs groups during a course will help us distinguish the points in time when targeted interventions to foster students' motivation are most supportive and will thus be most efficient and (cost-)effective.

2.4 Context: Mandatory first-year course on the ethics and history of technology

We report on a medium-sized Dutch technical university with a staff of 3000, catering to an average of 6000 undergraduate and 4000 master students. We briefly indicate how we aimed for competence (C), autonomy (A), and relatedness (R) in this design. The relevant USE basic course was the first in a set of four nontechnical courses mandatory for all undergraduate students (Bekkers & Bombaerts, 2017; G. Bombaerts & Doulougeri, 2019). It concerned an 11-week mandatory, first-year course on the ethics and history of technology given at the end of the second semester. In 2016, the year of our study, 1864 students from 15 different undergraduate engineering degree programs took the course, which was offered in two languages (native Dutch and English) by 32 teachers and tutors from two research groups (one focused on history and the other on ethics). The students attended the lectures in eight groups of about 250 students each on two different days of each week of the course, and the weekly tutorials in 32 groups of about 60 students each. Groups of three students (R) selected a case (A) and followed a five-step cycle (van de Poel & Royakkers, 2007) to analyze the ethical aspects and historical forerunners, and based on the results, proposed improvements to current real-life technologies (C). We focus on these course elements that have an important role in our analysis; we refer to G. Bombaerts and Spahn (2019) for a more detailed explanation of the course.

The first half of the course aimed to introduce new concepts and methods. It had one combined introduction lecture and several lectures dedicated to history or ethics only (C). The second half of the course aimed to cover gained knowledge. After Week 6, the lectures were combined to integrate the knowledge (C) and provide the necessary input for a group assignment. In the first part of the course, students worked together (R) on the first four steps: problem definition, problem analyses, formulation of possible solutions based on history and ethics separately in which students could make choices (A), and evaluation of proposed solutions. After Week 6, students integrated their work to come to a
general real-life conclusion (Step 5) (C). The assignment accounted for 40% of the overall course grade. Tutors gave written feedback in Week 3 on the first two steps of the assignment, in Week 7 on the ethical solutions and potential links to the general conclusion, and in Week 8 on the solutions based on the history part (R, C). Three multiple choice interim quizzes were added to help students better prepare for the final multiple-choice exam (C). These quizzes were conducted online, in which each student got a randomized set of questions about different aspects of the course readings. During the first half of the course, two quizzes were offered. In Week 8, the last quiz was offered. The two best quiz results of the three online quizzes students could take (A) added up to 10% of the overall course grade. The final exam was a multiple-choice exam on ethics and history, for the remaining 50% summing up to the GPA.

Table 1 gives an overview of the course lectures, assignments, tutor feedback, quizzes, and the final multiple-choice test.

The USE basic course repeatedly yielded low course evaluation (item: “On a scale from 1–10, how would you rate this course?”) scores, that is, an average of 5.6 for the past 3 years on, with substantial standard deviations (SD average of 1.9). This is in line with the culture of disengagement reported in the literature (Lonngren, 2021). The course evaluation results showed a wide score range (with an average of 17% of the students who rate the course with a one to three and 13% with scores that range from 8 to 10). It was decided to analyze motivational dynamics throughout the course to differentiate between personal factors (“Do students already show amotivation at the start of the course?”) and social factors (“Does the course demotivate motivated students?”) to increase understanding of how students’ motivation for learning can be improved taking basic needs into account.

3 | RESEARCH QUESTIONS

Based on the above, we sought to answer the following two research questions:

1. Which distinct profiles can be identified based on individual basic psychological needs in engineering students enrolled in the USE basic course?
2. In what way do motivation types evolve during the USE basic course for students with different basic needs profiles?

4 | METHOD

4.1 | Procedure

All students of the USE basic course in 2016 received an invitation by email to fill out an electronic questionnaire at three time points during the course (Weeks 1, 6, and 11; refer to Table 1). They were informed they would not receive any compensation for their participation and were asked for their informed consent. The different datasets and the students’ grades were merged by the university’s quality assurance team. We subsequently evaluated the anonymized master file in agreement with national and university privacy policies.

The measurement in the first week of the course (Q1) was designed to get input about the students’ first impressions of the course. At the half-way assessment at Week 6 (Q6), all students attended history and ethics lectures, tutorials, received first tutor feedback, and took two online quizzes. As the first half was aimed at learning new things and the
second half was aimed to converge gained knowledge from a course redesign perspective, this was considered a significant moment to measure a second time. The final end-of-course assessment was scheduled for Week 11 (Q11) after the final written exam (Table 1).

4.2 | Instruments

All USE basic students were asked to complete a dedicated questionnaire about social factors in terms of various course elements, basic psychological needs, and motivation types, and consequences in terms of course appreciation. Course elements and basic needs were assessed at Q11, and motivation types and course appreciation at all three-time points (Table 2). Except for the 10-point Likert scale used for the overall course evaluation item, all other items were rated on a 5-point Likert scale that ranged from one (“Don’t agree at all”) to five (“Fully agree”). In Table 3, we give one example for each item category.

For all parts of the questionnaire, exploratory factor analyses (EFAs) were performed. Principal axis factoring with an oblique rotation was used. The number of extracted factors was initially set to the expected number of factors based on theory. However, analyses with different extracted factors (based on scree-plot analysis) were also considered. Whenever possible, the factor solutions were compared with other data, for example, with other measurements within the same year or with data from another second-year USE course (n = 535). Results showed comparable factor solutions.

Course elements were assessed with an instrument developed by the authors: lectures (three items), the group assignment (six items), tutor feedback (six items), and final test (four items). Table 3 provides example items. An EFA confirmed the factor structure of these items in the four factors as expected. Together, the four factors explained 64% of the variance, and their reliabilities were 0.78 for lectures, 0.87 for assignments, 0.90 for tutor feedback, and 0.77 for the final test.

Basic needs were assessed with the Basic Psychological Need Satisfaction Scale (BPNS; SDT Research Network, n.d.), elaborated by Gagné (2003) from a basic need satisfaction at work scale (Ilardi et al., 1993). The use of the BPNS has been reported in EER (e.g., Cho et al., 2021; Stolk et al., 2018). Whereas Cromhout et al. (2018) report a limited application of the instrument in a university student population, Sheldon and Hilpert (2012) added evidence to the validity (for engineering education, refer to Douglas & Purzer, 2015) of BPNS to use the nine positively formulated items only. We, therefore, decided to use the positively formulated items only.

In our study, we assessed basic needs only once because of institutional limitations on the length of our questionnaires and because of the exploratory nature of our inquiry, as dynamic profiling is more complicated. As such, we are aware that we assume the students’ basic needs profiles to be stable for the duration of the course and hypothesize that motivation is dynamic throughout the course; and that this is a simplification, as basic need clusters are considered to be dynamic. In this exploratory inquiry, we assumed that asking for basic needs in Week 11 is the best option, as students can judge the course overall.

In our EFA on basic needs, all but one item loaded on the three expected factors. The exception was one item from relatedness, which in our analysis also loaded on autonomy. On data from the subsequent year, however, all nine items loaded into the factors as expected. As basic needs have a strong theoretical background, the item was not changed or moved to another factor. The three basic need factors together explained 66% of the variance (and 64% in the subsequent year). Reliabilities for Q11 and for the second-year course were 0.67 and 0.66 for autonomy, 0.79 and 0.77 for relatedness, and 0.70 and 0.61 for competence, respectively.

<table>
<thead>
<tr>
<th>Topics</th>
<th>Instrument</th>
<th>Reference</th>
<th>Validation</th>
<th>Q1</th>
<th>Q6</th>
<th>Q11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course elements</td>
<td>Own, factor level</td>
<td>-</td>
<td>-</td>
<td>X</td>
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<tr>
<td>Basic needs</td>
<td>Basic Psychological Need Satisfaction Scale (BPNS)</td>
<td>SDT Research Network (n.d.)</td>
<td>Sheldon and Hilpert (2012)</td>
<td>X</td>
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<tr>
<td>Course appreciation</td>
<td>Own, item level</td>
<td>-</td>
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<td>X</td>
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Note: More detailed instrument information can be found in Table 3.
Student motivation for learning was measured in Q1, Q6, and Q11 with the Self-Regulation Questionnaire—Academics (SRQ-A) (SDT, 2014). The instrument evaluates five types of motivation (intrinsic, internalized, introjected, extrinsic, amotivation) that consist of four items per scale (Vansteenkiste et al., 2005). The use of the SRQ-A has originally been developed and been validated for primary and secondary school children (Ryan & Connell, 1989). Evidence has been collected for university students as well (Niemiec et al., 2006; Van den Berghe et al., 2013). SRQ-A has been used in EER (e.g., Gero & Abraham, 2016; Gero & Mano-Israeli, 2017; Koh et al., 2010) and has shown to be a moderately reliable measure stable across subscales and across studies, including higher education contexts (Bolling et al., 2018). In our EFAs, most items loaded into factors as expected with two main exceptions. First, one item of the extrinsic factor (“I am motivated to study for the USE basic course because I’m supposed to do so.”) consistently did not load on any factor, therefore, this item was removed from further analyses. Second, all items from intrinsic and internalized loaded on one factor in all three measurements and the second-year course. In SDT, the combination of intrinsic and internalized is called autonomous motivation. The similarity is that both types of motivation stem from an internal locus of control. In further analyses, the items from intrinsic and internalized were further treated as one scale named autonomous motivation. The four factors autonomous, introjected, extrinsic, and amotivation accounted for between 64% and 69% of the variance for the three different measurements and the extra measurement in the subsequent year. Reliabilities in Q1, Q6, and Q11 for autonomous motivation ranged from 0.89 to 0.92, between 0.75 and 0.77 for introjected motivation, between 0.78 and 0.86 for extrinsic motivation, and between 0.81 and 0.85 for amotivation.

As to the appreciation of the evaluation of the course as a whole, the students’ rated its relevance and their enjoyment, as well as their overall course evaluation (one item each).

### 4.3 | Participants

It was our university’s policy in 2016 not to ask for gender, ethnicity, and age for admission or research purposes. As the USE basic course is mandatory for all first-year engineering students, we can derive from the 2015–2016 cohort that
of the total of 1864 first-year students, 27% were female, 10% had an international background, and most were 18 and 19 years of age at the time of testing. With 14.2%, 23.6%, and 33.6%, respectively, we obtained acceptable response rates at Q1, Q6, and Q11 (Nulty, 2008). As motivation is reported to influence GPAs (French et al., 2005), it is a potentially important variable to establish any self-reflection bias. Students received grades that ranged from 0 to 10, with 5.5 the minimum to pass the course. At Q1, the respondents and nonrespondents showed no significant differences in final grades. Both at Q6 and Q11, the responders had higher grades than the nonresponders (Q6: $M = 6.86$, $SD = 1.21$ vs. $M = 6.48$, $SD = 1.19$, $t(1694) = 5.73$, $p < .001$, Pearson’s $d = 0.33$ and Q11: $M = 6.81$, $SD = 1.22$ vs. $M = 6.43$, $SD = 1.12$, $t(1416) = 6.55$, $p < .001$, Pearson’s $d = 0.32$). These results indicate some self-selection bias, with higher-performing students more likely to complete the survey.

### 4.4 Analyses

Variable-centered approaches use analyses like correlation or regression that explain associations between variables. When applied to a list of variables $Y_i$, the result then is a list of unconnected relations in the form $Y_i = \sum_j w_{ij} \ast variable_j$. A person-centered approach classifies groups of individuals who share particular attributes or relations among attributes. A typical analysis here is cluster analysis that attributes objects to different groups according to specific criteria of specific variables. Cluster analysis groups objects in such a way that objects in one cluster are, according to the specified criteria and variables, more related to each other than to those in other clusters (Everitt et al., 2011). Once these distinct clusters are found (e.g., based on variable), a connected set of variables $Y_i$ can be determined that leads to specific profiles explaining differences in patterns of development across these profiles.

In our research, a two-step cluster analysis was conducted to identify homogeneous groupings of responders with distinct basic needs profiles as is customary in higher education research (i.e., Canrinus et al., 2011; Ferla et al., 2009; Papinczak, 2009; Valle et al., 2008) and recommended, especially when the number of clusters is uncertain (Zhang et al., 1996). The silhouette measure for cohesion and separation $S$ is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation). It provides thresholds for poor ($\leq 0.25$), fair ($\leq 0.5$), and good (>0.5) models. It indicates that the object is well-matched, based on a specific metric, to its own cluster and poorly matched to neighboring clusters (Wendler & Gröttrup, 2016). Text-book examples sometimes show visibly distinct clusters, but strong cluster results can be very strong without visible differences. $Z$-scores (the difference of the cluster mean and the overall population mean, divided by the overall SD as such giving a measure of how many SDs the raw score differs from the population mean) can be interpreted as effect sizes, with $0.5 > Z \geq 0.2$ a small effect, $0.8 > Z \geq 0.5$ a medium effect, and $Z \geq 0.8$ a large effect (Cohen, 1988). For determining the multivariate effect $F$-values were reported based on Pillai’s trace value, since $p < .001$ for the Box’s tests of the assumption of the equality of covariance matrices. Differences across the four clusters for course elements, motivation, and consequences were analyzed with MANOVAs and motivation change with ANOVA. Here, $\eta^2$ is the effect size, with $\eta^2 = 0.01$ indicates small, $\eta^2 \geq 0.06$ medium, and $\eta^2 \geq 0.11$ large effects (Cohen, 1988).

We performed two types of analysis to explore whether the types of motivation shifted differentially during the course for the different student profiles. First, for each cluster separately, paired sample $t$-tests were used to analyze whether motivational changes had occurred between Q1 and Q6 and between Q6 and Q11, where we classified Cohen’s effect sizes $0.5 > d \geq 0.2$ as small, $0.8 > d \geq 0.5$ as medium, and $d \geq 0.8$ as large (Cohen, 1988). Second, we compared the increases and decreases in motivation for the four clusters computed between Q1 and Q6 ($\Delta Q1Q6$) and between Q6 and Q11 ($\Delta Q6Q11$). MANOVAs and Tukey’s post hoc tests were used to determine the differences between the changes across clusters. $\eta^2$ was used to reflect the effect size, with $\eta^2 \geq 0.01$ small, $\eta^2 \geq 0.06$ medium, and $\eta^2 \geq 0.11$ large sizes (Cohen, 1988).

### 5 RESULTS

#### 5.1 Four distinct basic needs profiles

We performed two-step cluster analyses with log-likelihood distance measure with all three and with two of the three basic needs variables. Only the cluster analysis with competence and autonomy provided a silhouette measure for
cohesion and separation \( S \) for this model >0.5, which indicated good cluster quality. Figure 2 shows the differences between the cluster means in terms of \( Z \)-scores. The size ratio between the biggest and smallest cluster was 2.37. The predictor importance was 1.00 for competence and 0.89 for autonomy. For the two constituting dimensions competence and autonomy, the \( Z \)-scores were low-low, low-high, high-low, and high-high, respectively (refer to Figure 2b). Effect sizes based on the \( Z \)-scores for Clusters 1 and 4 were large and for Clusters 2 and 3 small and medium, respectively. The four clusters explained 73% and 69% of the variance in competence and autonomy, respectively (Table 4). This is in line with other research reporting on effect sizes of constitutive variables (refer, e.g., to Vansteenkiste et al., 2009).

The MANOVAs and post hoc \( t \)-tests showed clear differences between the four clusters. We found medium effect sizes for the differences for lectures, introjected regulation, and external regulation. The other course elements, autonomous motivation, amotivation, enjoyment, relevance, and overall course evaluation, yielded large effects across clusters. The four clusters differed, with large effect sizes, in the course element variables, Q11 motivation types, and the consequence variables with Pillai’s traces of 0.44, 0.34, and 0.37, respectively. The differences across clusters for GPA have a small effect size only (\( F(757, 3) = 4.4, p < .05, \eta^2 = 0.02 \)).

The role of Cluster 2 was most noticeable. For some variables, the Cluster 2 mean fell in between those of Clusters 1 and 3, but for other variables (e.g., tutor feedback or final test), there were no significant differences between Clusters 2 and 3. For external regulation, students in Cluster 2 scored significantly lower compared to the other three clusters; and relatedness was higher than Cluster 3.

5.2 Cluster-specific shifts in motivation during the course

We first ran paired sample \( t \)-tests for each cluster separately to analyze whether there were significant changes in motivation from Q1 to Q6 and from Q6 to Q11. Introjected and external regulation had not changed significantly for any of the clusters. Table 5 and Figure 3 show the results for amotivation and autonomous motivation.

Second, increases or decreases in motivation across clusters were calculated between Q1 and Q6 (\( \Delta_{Q1Q6} \)) and between Q6 and Q11 (\( \Delta_{Q6Q11} \)) with ANOVAs and Tukey’s post hoc tests. From Q1 to Q6, autonomous motivation had decreased significantly, with a medium effect size for all clusters (Table 5). The post hoc tests showed no significant differences between clusters for these decreases (Table 4). After Week 6, autonomous motivation remained stable for the entire group. However, it had kept on decreasing significantly for Cluster 1, with medium effect size, while it had remained stable for Clusters 2 and 3 and had increased significantly, with medium effect size, for Cluster 4 (Table 5). For \( \Delta_{Q6Q11} \) autonomous motivation thus showed significant differences between Cluster 1, Clusters 2 and 3, and Cluster 4, respectively, with medium effect sizes (Table 4).

Amotivation remained stable from Q1 to Q6 for Cluster 4, had slightly increased for Clusters 2 and 3, while it had increased, with large effect size, for Cluster 1 (Table 5). The changes in Clusters 2, 3, and 4 were not significantly different from each other for \( \Delta_{Q1Q6} \) amotivation, but significantly different from Cluster 1 (Table 4). From Q6 to Q11,
Cluster 4 had again remained stable, while Clusters 1, 2, and 3 all showed an increase, with small effect sizes (Table 5). \( \Delta Q6 \) amotivation thus revealed significant differences between Cluster 4 on the one hand and Clusters 2 and 3 on the other hand, with medium effect sizes (Table 4).

### 6 | DISCUSSION AND IMPLICATIONS

#### 6.1 | Implications for research

The analysis provided support for a person-centered basic needs approach in engineering education complementary to the variable-centered approach. It revealed four distinct basic needs profiles in the 2016 USE basic course. The basic needs competence and autonomy were constituting dimensions. Although relatedness was less important for the cluster...
Table 5: The means (M), standard deviations (SD), Pearson’s correlation coefficients and significance (r*), mean differences and significance (ΔM*), and effect sizes (Cohen’s d) for all the respondents (A) and the four clusters dissatisfied (1), autonomy (2), competence (3) and satisfied (4) between Q1 and Q6 and between the Q6 and Q11 assessments for autonomous motivation and amotivation

| N | M   | SD | M   | SD | r   | ΔM* | d   | Q1–Q6 | N | M   | SD | M   | SD | r   | ΔM* | d   | Q6–Q11 |
|---|-----|----|-----|----|-----|-----|-----|-----|-------|---|-----|----|-----|----|-----|-----|-----|-------|
|   |     |    |     |    |     |     |     |     |       |   |     |    |     |    |     |     |     |       |
| Autonomous motivation | | | | | | | | | | | | | | | | | |
| A  | 117 | 2.86| 0.77| 2.49| 0.80| .73*| −0.37*| −0.47| 266  | 2.42| 0.74| 2.41| 0.85| .66*| −0.01| −    |
| 1  | 12  | 2.33| 1.00| 1.82| 0.76| .85*| −0.51*| −0.57| 35   | 2.02| 0.75| 1.62| 0.72| .45*| −0.40*| −0.54|
| 2  | 21  | 3.10| 0.78| 2.60| 0.71| .84*| −0.50*| −0.66| 67   | 2.54| 0.71| 2.52| 0.75| .67*| −0.01| −0.02|
| 3  | 25  | 2.79| 0.66| 2.40| 0.75| .77*| −0.39*| −0.56| 89   | 2.26| 0.68| 2.18| 0.75| .65*| −0.09| −0.11|
| 4  | 24  | 3.11| 0.68| 2.76| 0.70| .60*| −0.35*| −0.51| 70   | 2.74| 0.70| 3.02| 0.65| .62*| 0.28*| 0.42 |
| Amotivation | | | | | | | | | | | | | | | | | |
| A  | 177 | 2.15| 0.89| 2.34| 0.94| .61*| 0.19*| 0.21| 270  | 2.39| 0.90| 2.63| 1.04| .60*| 0.23*| 0.24 |
| 1  | 12  | 2.29| 0.86| 3.23| 0.98| –   | 0.94*| 1.01| 35   | 2.95| 0.82| 3.14| 1.12| –   | 0.19  | 0.20 |
| 2  | 21  | 2.00| 0.92| 2.21| 0.80| .55*| 0.21  | 0.25| 68   | 2.33| 0.78| 2.76| 0.96| .56*| 0.44*| 0.50 |
| 3  | 25  | 2.16| 0.92| 2.26| 0.98| .83*| 0.10  | 0.10| 89   | 2.54| 0.98| 2.85| 0.96| .65*| 0.31*| 0.32 |
| 4  | 24  | 1.99| 0.87| 2.04| 0.83| .45*| 0.05  | 0.06| 72   | 2.00| 0.77| 1.95| 0.83| .57*| −0.05| −0.06|

*p < .05.

Figure 3: Patterns of (a) autonomous motivation and (b) amotivation for the four clusters (1) dissatisfied, (2) autonomy, (3) competence, and (4) satisfied at the three points in time (Week 1 [W1], Week 6 [W6], and Week 11 [W11]).
determination, it did differ significantly across clusters. The result of Leon and Liew (2017) and K. Trenshaw et al. (2016) that relatedness was the crucial basic need for their students should not be interpreted as conflicting. The interaction between the different individual factors of the students and their different social factors led to different basic needs. The measurement in both inquiries was sensitive enough to reveal the relevant basic needs.

Based on our quantitative findings and lacking further qualitative findings, we formulate a careful interpretation of the clusters. The first cluster seemed to include students for whom the USE basic course did not offer anything to hold on to, as they lost their autonomous motivation along the course. We propose to characterize the students in this cluster as “dissatisfied” as they showed vulnerability in the course and were able to fulfill their basic needs. The second and third clusters also seemed to comprise of students that struggle with the lack of support provided by the course, but they seemed to find some relief in applying their own strengths to find their own way around. As students in these clusters have high autonomy with low competence; or high competence with low autonomy, we labeled the clusters “autonomy” and “competence,” respectively. The fourth cluster seemed to consist of students who maintain their autonomous motivation, limit their amotivation, and perceive their basic needs as sufficiently “satisfied” by what the course could offer them.

We hypothesized that the students with an autonomy profile (Cluster 2) and a competence profile (Cluster 3) mainly relied on one basic need to fathom and complete the course. This could explain why external regulation was reported significantly less in Cluster 2 compared to the other three profiles. Suppose students report to be highly autonomous but rate their competence basic needs as low. In that case, it threatens their autonomy if they perform an activity because of an external driving force, but it also implies risks because of the perceived lack of competence. The Cluster 2 students reported high autonomy and low competence and rated assignment, autonomous motivation, enjoyment, relevance, and overall course evaluation significantly lower than those in Cluster 3. This underscores that autonomy and competence play different roles. It strengthens both the argument for a person-centered approach in teaching and the need for the two constituting dimensions in the USE basic course.

The results of the basic needs cluster analyses in the fields of sports, elderly care, secondary education, and our results do not paint a clear and uniform picture, which raises new questions. We hypothesize that the number and nature of clusters and the relevance of the basic needs variables might depend on a student-specific interplay between personal (perceptions) and social (course) factors. A next research step could then be to look more closely at this interaction. Here, regression analysis with more potentially relevant individual variables (e.g., demographics, personality traits, and states, learning preferences, approaches to learning, or attitudes about the nature of knowledge) and more and empirically better-defined items and factors for course elements may help predict basic needs patterns better for the different profiles to thus facilitating targeted changes to course designs.

With our findings on profile-specific motivational changes during the course, we have added to the EER literature on motivation types and specified the significance levels and effect sizes for the changes in autonomous motivation and amotivation in the first and second half of the course for each basic needs cluster separately, as well as the differences in motivation increases or decreases over time across clusters. We found no changes in controlled motivation. Our results confirmed the findings of Vanasupa et al. (2010) and Dillon and Stolk (2014) within EER that motivation types are dynamic in nature. A next research step could go from a stable cluster approach to an analysis in which the basic needs and the related profiles are also considered dynamic.

### 6.2 Implications for teaching and learning

The results enabled us to analyze and redesign the case-based learning course. During the first 6 weeks, all clusters, on average, increased in amotivation for learning, but the dissatisfied profile significantly increased more. The students had a tight schedule to learn both ethics and history methods to apply to a case (infringing students’ autonomy), and the course did not sufficiently support the new competencies that the students needed (infringing students’ competence). The second half was focused on concluding. Lectures used the materials of the first half to make more meaningful connections, the schedule was less tight, and the tutors gave more written feedback. No change in autonomous motivation was observed for the entire group, but Cluster 1 showed a strong decrease and Cluster 4 a strong increase (Table 5).

The change in the competence and autonomy between the first and second parts of the course seemed sufficient for Cluster 4 but not at all for Cluster 1. We hypothesized that further course improvements related to these two basic needs would eventually enable students in Cluster 1 to satisfy their needs and foster their autonomous motivation. Our
results showed that the differences in basic needs profiles did not play an important role in the students’ appreciation of the lectures. However, the way the course offered the assignment, the tutor feedback, and the final test were significantly differently appreciated by students across clusters. We thus decided to focus on these course elements for a further redesign.

This led us to develop a scalable (G. Bombaerts, 2020) challenge-based learning version of the USE basic course, in which students work on technical and ethical aspects of a challenge of an external stakeholder to motivate the first-year’s engineering students for the ethics and history courses, hoping to contribute to their diverse future role as responsible engineers (G. Bombaerts & Laes, 2007; Loui, 2005; Pesch et al., 2020; Walther et al., 2017). The redesign needed a multilevel review focusing on teacher and institutional expectations and practices (Martin et al., 2021). As the right level between challenge and control, competence was further optimized by linking the assignment to technical challenges and reducing the required written language skills. The multiple-choice test was replaced by a report that had to be presented for the stakeholder in a celebratory end-event. We aimed to increase autonomy, as the feeling of being supported to be able to make meaningful choices in an activity. We simplified the course as we excluded history and kept ethics as a discipline (G. Bombaerts & Spahn, 2019), and as such, created more space and focused in the course. We offered weekly structured contact moments that allow for individual flexibility (G. J. T. Bombaerts et al., 2018). Oral feedback was organized in weekly coaching sessions (van Diggelen et al., 2019) to support students to give meaning to the process they went through. The number of respondents was too small to perform cluster analysis in the way we did in this article, but the analysis showed that a redesign based on the cluster analysis led to results for the entire group that was significantly better for competence, autonomy, and intrinsic motivation compared to the classical approach (G. Bombaerts et al., 2021).

6.3 Limitations

Several limitations of our research should be mentioned. First, we opted for SDT because it allows a fine delineation of differences and dynamics in motivation for learning, but other theories such as personality-based motivational theories (Prentice et al., 2019) and the expectancy-value motivational theory, for instance, Van den Broeck et al. (2010), might have shed more light on the interaction between social and personality factors. We indicated the limitations of the collection of evidence for the validity of the BPNS and SRQ-A for a university student population that were formulated after the questionnaire was taken. Results showed that there was sufficient evidence to support our conclusions. However, EER should clearly take the issue of basic needs of satisfaction and frustration into account by analyzing the validation of instruments to better understand this difference. Next, our study evaluated student needs during one version of an 11-week, mandatory introductory course of ethics and history of technology offered at a single technical university, with data collected at three time points only. One could consider this a rather unrefined approach and question whether we have pinpointed the moments at which certain changes in motivation were triggered and how this differed for the four clusters. As mentioned, institutional policies on questionnaires and research design prevented us from including more assessments. We feel that our core finding, that motivation types are dynamic, still holds despite these shortcomings. However, other studies (Dillon & Stolk, 2012) also showed that students’ endorsements of the various motivations changed significantly within the duration of a single course. Therefore, it was deemed that the specific nature and content of the USE basic course itself were less relevant. Other general or dedicated courses in the engineering curriculum might also benefit from the insights we gained from our evaluation.

Our study further lacked detailed information on gender and ethnicity (Pawley, 2017), and we only reported on the nonresponse bias as a function of the students’ final grades. As motivation can influence grades (French et al., 2005), the effect size for differences in GPA across clusters was small ($\eta^2 = 0.02$), but given the empirical information we were able to collect, it is difficult to judge the impact of this bias. Future research is advised to address this issue, although comparison with previous EER findings is difficult since most studies did not investigate the bias either. Also, we assumed the basic needs profiles as assessed in Week 11 to be stable for the duration of the course and motivation to be dynamic throughout the course. However, because SDT posits that basic needs are also dynamic, researchers should monitor changes in profiles over time and as frequently as is necessary for the course under study. Basic needs clusters taken early in the course might have been different from the clusters found in this research. Such research could result in different specificities, like other constitutive variables or students shifting from one cluster to another. However, the main finding that a basic needs measure at the end of the course can reveal different motivational dynamic patterns remains intact. Last, some of our variables were rather generally formulated, including lecture and assignment as two
of the course components. Since ours was an exploratory study, we felt and argued it provided sufficient information to consider course modifications and could serve as a starting point for further educational evaluations. More and more well-defined variables will help us gain more detailed insights and contribute to more (cost)efficient, tailored instructional models.

7 Conclusion

Based on distinct roles of the basic needs for competence and autonomy, the present study identified four different student profiles with important differences in course appreciation, motivation for learning, and motivational dynamic. As such, it provided support, in line with educational psychology, for a person-centered motivation approach in engineering education.

The person-centered approach is promising in engineering education design to answer differences in students' basic needs to improve the quality of learning for all. We described important profile-specific motivational dynamics during a course despite the fact that there were no changes for the average of the entire group of students as a whole. This illustrates that educators can better explore ways to redesign course components to coincide more optimally with their students' needs and motivation types at any one time point, and thus, optimize course appreciation and outcomes taking into account student differences.

We also showed the person-centered approach could add important insights complementary to the variable-centered approach in EER on (dynamics of) motivation for learning. We proposed that the number and nature of needs clusters rely on the role of the constituent need variables that, in turn, depend on the interplay of personal and social factors. Further research should analyze how personal and social factors together influence students' basic needs and how targeted modifications to the overall course design can support students with different needs and motivation profiles at different times during a training course.

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