## Chapter #5

# PRE-SERVICE ENGINEER EDUCATORS LEARNING MATHEMATICS: MAPPING THE LIVED COMPLEXITY

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**ABSTRACT**
In this paper, we adopt a systemic perspective to investigate the teaching of mathematics in ASPETE, which is a tertiary education institute in Greece that offers a two-faceted degree: an engineer degree and a pedagogical degree as engineer educator. We focus on the complex lived reality of first year Electrical Engineers and Mechanical Engineers students through a multileveled affective mapping of their studying in ASPETE, including: approaches to study, confidence in learning mathematics, conceptions about mathematics and its role in their studies and career, and views about mathematics teaching effectiveness (considering both what they actually experienced and what they would prefer to experience). The students were found to show a lack of preference for the surface approach (though not combined with a preference for a deep approach), a neutral-positive confidence in learning mathematics, and to be satisfied by the teachers' effectiveness. Confidence in learning mathematics appeared to be central in the identified dynamic affect system, whilst their conceptions about mathematics seemed to be related with the desired characteristics of mathematics teaching. The students of the two departments differed in their levels of confidence in learning mathematics, which we posit that is linked with the qualitatively different affective complexity they experience.

*Keywords:* system, approaches to study, mathematics teaching effectiveness, mathematics conceptions, mathematics confidence.

## 1. INTRODUCTION

The modern sociocultural interactions appear to entail a continuously increasing level of quantitative and logical reasoning skills. Moreover, mathematics is at the crux of the contemporary curricula and the broader educational systems, whilst mathematics is also the language of communicating and producing scientific results. In this study, we focus on the role of mathematics in ASPETE, a Greek tertiary education institute, which offers its graduates both an engineer degree and a pedagogical degree as engineer educator (who may teach in vocational high schools in Greece). This inherently two-faceted degree constitutes a complex, interdisciplinary educational environment, within which complex professional identities are formed (Garner, & Kaplan, 2019; Nersessian, & Newstetter, 2014; Osbeck, & Nersessian, 2017). In a broader research project (Mathematics education and Technological Education; MATHETE), we adopted a systemic perspective (Moutsios-Rentzos, & Kalavasis, 2016) and built upon previous studies (Moutsios-Rentzos, & Kasimati, 2014) to investigate mathematics teaching and learning in ASPETE. In this paper, we report aspects of that broader project focusing on the lived complexity of first year Electrical Engineers and Mechanical Engineer students of ASPETE.

## 2. LEARNING MATHEMATICS IN ASPETE: A MULTILEVELED AFFECTIVE MAPPING OF THE LIVED COMPLEXITY

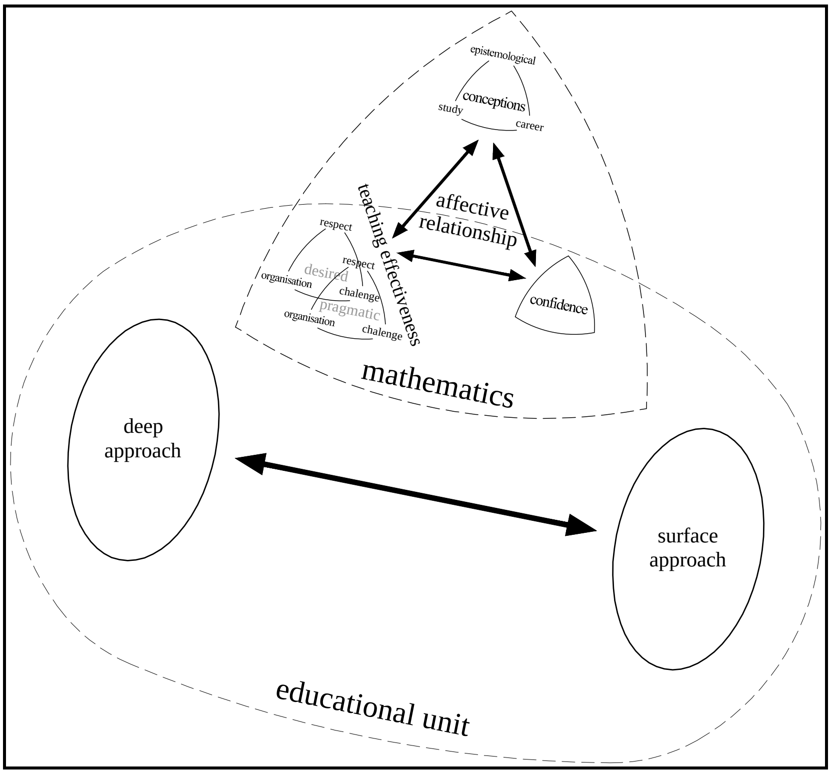
A system is defined as a complex whole, the parts of which are interrelated towards specific goals, thus significantly differing from a mere "heap" of parts (Bertalanffy, 1968). A system is characterised by its objective, its structure and behaviour (including, its elements, subsystems, boundary, connectivity, functions etc), thus being identified and differentiated by its environment. It should be noted that systems "vary in their openness (referring to their level of interaction with its environment and other systems), complexity (referring to the number of parts and their links) and dynamic (referring to the volume and speed of systems' input and output)" (Moutsios-Rentzos, & Kalavasis, 2016, p. 100). Following these, the educational units may be viewed as systems that function within the broader educational system and, subsequently, researchers approach the mathematics education phenomena through a systemic approach (see, for example, Begg, 2003; Chen, & Stroup, 1993; Davis, 2018; Davis, & Simmt, 2003; Wittmann, 2001, 2021). Within the educational system the various protagonists act and interact in diverse and multiple roles, as well as within and across their various subsystems (such as the school class; Cobb, & Jackson, 2008).

Hence, in this study, ASPETE may be conceptualised as an open learning system, being at the same time a subsystem of the broader educational system and the social system (cf. Kalavasis, & Kazadi, 2015). We drew upon Moutsios-Rentzos and Kalavasis (2016) to include in our investigations about mathematics the broader experience with studying in ASPETE. Furthermore, the students' (including pre-service teachers) broader studying experience in an educational unit is intertwined with their narrower experience with teaching and learning mathematics (Engelbrecht, Bergsten, & Kågesten, 2012), as well as with their affective relationship with mathematics is crucially linked with the students' educational outcomes (Beswick, 2012; Lo, 2021; Pepin, & Roesken-Winter, 2014). The latter is also linked with the perceived relationships amongst mathematics and the future workplace and its tools (Fitzsimons, 2001, 2013; Triantafillou, & Potari, 2010). Thus, we map the students' relationship with studying in ASPETE, their affective relationship with learning mathematics in ASPETE, as well as their interlinkings. Our approach is diagrammatically summarised in Figure 1 (drawing upon Moutsios-Rentzos, & Kalavasis, in preparation) and is discussed in the following paragraphs.

The students' broader studying experience in ASPETE is investigated through their *approaches to study* (Marton, & Säljö, 1976), referring to the specific manner in which students respond to a study situation. Two main approaches have been identified: a *deep approach* refers to focusing on the meaning and the ideas contained in a task, whilst a *surface approach* refers to focussing on the superficial characteristics and requirements of a task (see, also, Biggs, 2001; Entwistle, McCune, & Walker, 2001). In an educational unit, approaches to study may be conceptualised as the result of the constant negotiation between the students' learning characteristics and the requirements of the specific learning environment, as reflected on the students' academic outcomes.

In our approach, the students' affective relationship with learning mathematics, conceptualised as a *dynamic affect system* (Pepin, & Roesken-Winter, 2014), constitutes of three interacting components: a) *conceptions about mathematics*, b) *confidence about coping with mathematics*, and c) *views about mathematics teaching effectiveness*. Considering conceptions about mathematics, we drew upon our systemic perspective to consider mathematics within diverse systems: within the system of scientific disciplines, within the educational system, and within the occupational system. The work of Wood, Petocz and Reid (2012) fits with this, as they investigated the conceptions of undergraduate students about their epistemological conceptions of mathematics, their conceptions about the role of mathematics in their future studies and in their future career. Their findings suggest that the epistemological conceptions about mathematics may be classified as: a) 'numbers/components' (individual and isolated components, techniques and calculations), b) 'abstract/models' (models of the real-world phenomena), and c) 'life' (a way of thinking and interpreting the world). The conceptions about the role of mathematics in their future studies and career, appeared to be: a) practical (focused on calculations, problem solving, and logical thinking), b) generic (referring to a generic mathematical way of thinking and of its importance in studies and career), and c) (lack of) knowledge (referring to the lack of knowing of the exact role of mathematics in studies and career).

*Figure 1.*
*Learning mathematics in the educational unit: a mapping of the lived complexity (drawing upon Moutsios-Rentzos & Kalavasis, in preparation).*




Furthermore, we included in our mapping the students' confidence about learning mathematics, as well as their views about effective mathematics teaching. Fennema and Sherman (1976) developed the widely cited Fennema-Sherman Mathematics Attitude Scales, which included a scale that identifies the degree of confidence that an individual experiences with respect to his/her "ability to learn and to perform well on mathematical tasks" (p. 326). Considering mathematics teaching effectiveness, we chose to consider the broader educational literature to obtain a broader perspective to teaching effectiveness (Creemers, & Kyriakides, 2008; Muijs, & Reynolds, 2017). Furthermore, in our systemic investigations, we drew upon Moutsios-Rentzos and Kalavasis (2016) to differentiate the *pragmatic representation* of mathematics teaching effectiveness (referring to the perceived phenomenon as actually occurring in the educational unit) from the *desired/intentioned representation* (referring to the desired state of the phenomenon). Following these, for the purposes of this study, we adapted the research of Patrick and Smart (1998) about teaching effectiveness. They conceptualised teaching effectiveness to consists of three dimensions, namely: *respect for students*, *ability to challenge students*, *organisation and presentation skills*. In this project, in line with our dynamic affect system approach, the tri-faceted conceptualisation of teaching effectiveness was conceptualised to include both a pragmatic representation and a desired/intentioned representation (see Figure 1).

Consequently, in this study, we attempt to obtain a mapping of the *lived complexity* of learning mathematics in ASPETE, through a *multileveled affective mapping*. First, we investigated the *narrower* affective relationship with mathematics; a dynamic affect system including: the students' conceptions (epistemological, studies, career), their confidence about coping with mathematics, their views about mathematics teaching effectiveness (pragmatic, desired/intentioned) and their links. Moreover, we explored the *broader* relationship with studying in ASPETE through the students' approaches to study. Furthermore, we focussed on the links between the broader and the narrower relationship. Finally, considering that a different lecturer was teaching mathematics the prospective Electrical Engineers from the one teaching the prospective Mechanical Engineers, that the departmental affiliation (Bingolbali, Monaghan, & Roper, 2007) and the related professional identity differ, and that their mathematics teaching experiences may be different (since different lecturers were teaching in the two departments) and may be also linked with different broader studying experiences, we investigated whether the affective relationships are differentiated between the students of the two departments.

## 3. METHODS AND PROCEDURES

The study was conducted with 91 first-year of ASPETE (N=91; 17 females) in the end of the first semester of the academic year 2018-2019: 48 of them were following an Electrical Engineer degree and 43 were following a Mechanical Engineer degree. A five-section questionnaire was employed, including a section about demographic details (Section A) and four sections about approaches to study, mathematics conceptions, confidence about mathematics and mathematics teaching effectiveness. In particular:

Section B. Approaches to study were identified by Revised Two-Factor Study Process Questionnaire (R-SPQ-2F; Biggs, Kember, & Leung, 2001), as employed by Kasimati, Moutsios-Rentzos and Matzakos (2016) with ASPETE students, showing good cross-cultural validity and reliability. R-SPQ-2F consists of twenty (10 for each approach) 5-point Likert-type items.

Section C. The students' conceptions about mathematics were identified through the questionnaire of Wood et al. (2012) as employed by Moutsios-Rentzos and Kassimati (2014) with ASPETE students, showing its good cross-cultural psychometrics. The questionnaire consists of forty-six 5-point Likert type items organised in three parts, in accordance with the three dimensions it identifies: epistemological (16 items), studies (14 items), career (16 items).

Section D. The students' confidence about mathematics was identified through the Confidence in Learning Mathematics Scale (Fennema, & Sherman, 1976), consisting of twelve 5-point Likert type items.

Section E. The students' views about mathematics teaching effectiveness were identified through a *modified* version of Patrick and Smart's (1998) instrument. Each of the twenty-four, 5-point Likert type items of the original questionnaire was transformed to a dyad (in line with our aforementioned theoretical approach; see also Figure 1): the first part asking the students to reflect upon the actual teaching (*pragmatic*) and the second part upon their desired teaching reality (*desired*).

The descriptive and non-parametric inferential analyses were conducted with SPSS 25, including: One-sample Wilcoxon signed rank tests, Mann-Whitney *U* tests, and Kendall's tau correlations.

## 4. RESULTS

The results of our analyses concerning the students of both Departments together are summarised in Table 1. Considering the students' broader experience with studying in ASPETE, though they appear not to statistically significantly prefer a deep approach, they seem to statistically significantly move away from a surface approach. First, we focussed on the students' affective relationship with mathematics. All the measured aspects statistically significantly differed from the conceptual neutral (see Table 1). Nevertheless, the differences identified in confidence, the desired/intentioned reality of teaching effectiveness, an epistemological conception (life) and a career conceptions (knowledge) were not large enough to be assigned to a different characterisation from the conceptual neutral. Considering the remaining differences, the students' pragmatic representations about teaching effectiveness were on the positive ("agree"), suggesting their being satisfied by the experienced mathematics teaching in ASPETE. Regarding the pragmatic representation of teaching effectiveness, the students expressed their statistically significantly positive experiences in respect, organisation and challenge. Furthermore, they conceptualised mathematics as being abstract models, about techniques and calculations. Regarding the role of mathematics in their future studies, the noted the practical and generic aspect of mathematics, as well as their knowledge about its role. Considering their future career, they also seem to identify the practical aspect of mathematics, but they appear to be neutral ("neither agree, nor disagree") with respect to the generic aspect of mathematics and their knowledge of its role in their future career.

Furthermore, we investigated the links *within* the dynamic affect system about mathematics. Confidence in learning mathematics was found to be statistically significantly positively correlated with the pragmatic representation of respect and of challenge. Moreover, confidence was found be to statistically significantly positively correlated with seven of the nine measured conceptions (except for with mathematics being numbers/components and with the generic role of mathematics in their studies). Thus, it appears that confidence in mathematics is positively linked with multiple aspects of the mathematics affect system. Furthermore, regarding the links between teaching effectiveness and conceptions about mathematics, the students' conceptions about the generic aspect of mathematics in their future studies had a statistically significant negative correlation with their desire for more respect. Overall, it seems that within the dynamic affect system about mathematics, confidence in learning mathematics plays a central role by having immediate relationships with other affective aspects.

*Table 1.*
*Learning mathematics and studying in ASPETE: a mapping of the lived complexity.*

| | | *M* | *Mdn* | *P* | | *Deep*[8] | *Surface*[8] | *Confidence* |
|---|---|---|---|---|---|---|---|---|
| *Deep approach* | | 3.0[1] | 3.0 | 0.815[4] | | | | |
| *Surface approach* | | 2.6[1] | 2.6 | <0.001[4] | | | | |
| *Confidence in learning mathematics* | | 3.3[2] | 3.3 | 0.001[5] | *τ*[7] | 0.207 | -0.197 | |
| | | | | | *P* | 0.013 | 0.018 | |
| *Respect* | Pragmatic | 4.2[2] | 4.3 | <0.001[5] | *τ* | 0.222 | -0.128 | 0.184 |
| | | | | | *P* | 0.005 | 0.102 | 0.034 |
| | Desired/Intentioned | 3.3[3] | 3.0 | <0.001[6] | *τ* | 0.057 | -0.087 | -0.099 |
| | | | | | *P* | 0.503 | 0.308 | 0.297 |
| *Organisation* | Pragmatic | 3.9[2] | 4.0 | <0.001[5] | *τ* | 0.101 | 0.021 | 0.144 |
| | | | | | *P* | 0.226 | 0.803 | 0.126 |
| | Desired/Intentioned | 3.7[3] | 3.0 | <0.001[6] | *τ* | 0.026 | -0.097 | -0.057 |
| | | | | | *P* | 0.748 | 0.235 | 0.530 |
| *Challenge* | Pragmatic | 3.9[2] | 3.9 | <0.001[5] | *τ* | 0.264 | -0.159 | .0251 |
| | | | | | *P* | 0.001 | 0.043 | 0.004 |
| | Desired/Intentioned | 3.3[3] | 3.0 | <0.001[6] | *τ* | 0.133 | -0.056 | -0.015 |
| | | | | | *P* | 0.115 | 0.504 | 0.874 |
| *Conceptions* | Number/Components | 3.7[2] | 3.7 | <0.001[5] | *τ* | 0.100 | 0.098 | 0.124 |
| | | | | | *P* | 0.226 | 0.237 | 0.142 |
| | Modelling/Abstract | 4.0[2] | 4.0 | <0.001[5] | *τ* | 0.207 | -0.163 | 0.289 |
| | | | | | *P* | 0.014 | 0.054 | 0.001 |
| | Life | 3.3[2] | 3.3 | <0.001[5] | *τ* | 0.151 | -0.196 | 0.173 |
| | | | | | *P* | 0.067 | 0.018 | 0.041 |
| *Studies* | Practical | 3.9[2] | 4.0 | <0.001[1] | *τ* | 0.092 | -0.034 | 0.212 |
| | | | | | *P* | 0.267 | 0.688 | 0.013 |
| | Generic | 3.5[2] | 3.5 | <0.001[1] | *τ* | 0.061 | -0.074 | 0.204 |
| | | | | | *P* | 0.462 | 0.372 | 0.015 |
| | (lack of) Knowledge | 3.8[2] | 4.0 | <0.001[1] | *τ* | 0.241 | -0.008 | 0.302 |
| | | | | | *P* | 0.004 | 0.928 | <0.001 |
| *Career* | Practical | 3.7[2] | 3.8 | <0.001[1] | *τ* | 0.155 | -0.069 | 0.290 |
| | | | | | *P* | 0.063 | 0.414 | 0.001 |
| | Generic | 3.2[2] | 3.3 | 0.001[1] | *τ* | 0.187 | -0.073 | 0.229 |
| | | | | | *P* | 0.023 | 0.379 | 0.007 |
| | (lack of) Knowledge | 3.4[2] | 3.4 | <0.001[1] | *τ* | 0.221 | -0.084 | 0.249 |
| | | | | | *P* | 0.007 | 0.311 | 0.003 |

[1] '1': never or rarely true of me, '2': sometimes true of me, '3': this item is true of me about half the time, '4': frequently true of me. '5': almost always true of me. [2] '1': strongly disagree, '2': disagree, '3': neither agree, nor disagree, '4': agree. '5': strongly agree. [3] '1': considerably less frequently, '2': less frequently, '3': as frequently as it did, '4': more frequently. '5': much more frequently. [4] One-sample Wilcoxon signed rank test to the hypothesised median "3": "this item is true of me about half the time". [5] One-sample Wilcoxon signed rank test to the hypothesised median "3": "neither agree, nor disagree". [6] One-sample Wilcoxon signed rank test to the hypothesised median "3": "as frequently as it did". [7] Kendall's tau τ non-parametric correlation. [8] 'Deep': Deep approach, 'Surface': Surface approach, 'Confidence': Confidence in learning mathematics.

Subsequently, we considered in our investigations, the educational unit and the broader experience of studying in ASPETE. First, it was revealed that the students showed a lack of preference for the surface approach, though not combined with a preference for a deep approach.

Moreover, we investigated the links between the broader experience with studying in ASPETE and their narrower experience of learning mathematics in ASPETE. Confidence was statistically significantly positively correlated with the deep approach and negatively correlated with the surface approach. Thus, it appears that the students who in general prefer to learn about ideas and meaning are also more confident with learning mathematics. Moreover, regarding teaching effectiveness, surface approach was statistically significantly negatively correlated with a preference for challenge in teaching (pragmatic representation), whilst deep approach was statistically significantly positively correlated with challenge and respect in teaching (pragmatic representation). These findings may be related to the fact that respect in teaching is not clearly related to the subject matter of the teaching itself and, therefore, is conceptually incompatible with the surface approach. At the same time, the qualitative characteristics of deep approach are conceptually compatible with both respect and challenge in teaching. Finally, regarding the links amongst approaches to study and conceptions about mathematics, conceiving mathematics as being abstract and about models was statistically significantly positively correlated with deep approach and negatively with surface approach. Moreover, deep approach was statistically significantly positively correlated with the knowledge about the role of mathematics in their future studies and career, as well as with the generic aspect of mathematics in their future career. Overall, statistically significant links were found between the broader experience of studying in ASPETE and the narrow experience of learning mathematics, which suggest that learning mathematics is affected by the way that the students experience and relate themselves with ASPETE.

Following these, it is reasonable to assume that the aforementioned relationships may be linked with the Department of study, since their departmental affiliation (Bingolbali et al, 2007) is different and their mathematics teaching experiences may be different (since different lecturers were teaching in the two departments). Hence, we investigated whether there were any differences between the students of the two departments with respect of the aspects of learning mathematics and studying in ASPETE (see Table 2).

Considering the dynamic affect system about mathematics, the students following the Electrical Engineering degree were statistically significantly more confident in learning mathematics and more satisfied by the organisation aspect of the mathematics teaching, than those following the Mechanical Engineering degree. At the same time, the latter appeared to statistically significantly desire more organisation in the mathematics teaching. It should be stressed that the identified difference in the students' confidence is borderline a conceptual difference, in the sense that the Mechanical Engineers report "neutral;" confidence and the Electrical Engineers report a borderline positive confidence ('3.5'; see Table 2). The statistical significantly differences are clear in teaching effectiveness, as the Mechanical Engineers are "neutral" about the teaching organisation and strongly positive about their desire for more organisation. Moreover, the students of the two departments did not statistically significantly differ in their conceptions about mathematics. Finally, considering the broader experience about studying in ASPETE, no statistically significant differences were found in the students' approaches to study, suggesting that departmental affiliation and other aspects that may be linked with the different departments did not affect the students' experiencing and being related with ASPETE.

*Table 2.*
*Aspects of learning mathematics and studying in ASPETE: Mechanical Engineers and Electrical Engineers.*

| | | *Electrical Engineers* | | *Mechanical Engineers* | | *Mann-Whitney U* |
|---|---|---|---|---|---|---|
| | | *M* | *Mdn* | *M* | *Mdn* | *P* |
| *Deep approach* | | 3.0[1] | 3.0 | 3.0 | 3.1 | 0.891 |
| *Surface approach* | | 2.5[1] | 2.5 | 2.6 | 2.6 | 0.582 |
| *Confidence in learning mathematics* | | 3.5[2] | 3.5 | 3.1 | 3.1 | 0.018 |
| *Respect* | Pragmatic | 4.1[2] | 4.3 | 4.2 | 4.4 | 0.711 |
| | Desired/Intentioned | 3.3[3] | 3.0 | 3.3[3] | 3.1 | 0.679 |
| *Organisation* | Pragmatic | 4.2[2] | 4.4 | 3.4 | 3.1 | <0.001 |
| | Desired/Intentioned | 3.3[3] | 3.0 | 4.4 | 4.6 | <0.001 |
| *Challenge* | Pragmatic | 3.9[2] | 3.9 | 3.9 | 3.9 | 0.994 |
| | Desired/Intentioned | 3.3[3] | 3.0 | 3.4 | 3.7 | 0.342 |
| *Conceptions* | Number/Components | 3.8[2] | 3.8 | 3.6 | 4.0 | 0.154 |
| | Modelling/Abstract | 3.9[2] | 4.3 | 4.0 | 4.0 | 0.893 |
| | Life | 3.3[2] | 3.3 | 3.3 | 3.2 | 0.696 |
| *Studies* | Practical | 3.9[2] | 4.0 | 3.8 | 3.8 | 0.423 |
| | Generic | 3.6[2] | 3.5 | 3.4 | 3.5 | 0.300 |
| | (lack of) Knowledge | 4.0[2] | 4.0 | 3.6 | 3.7 | 0.074 |
| *Career* | Practical | 3.8[2] | 4.0 | 3.7 | 3.6 | 0.273 |
| | Generic | 3.3[2] | 3.3 | 3.2 | 3.3 | 0.416 |
| | (lack of) Knowledge | 3.6[2] | 3.4 | 3.3 | 3.4 | 0.113 |

[1] ‘1’: never or rarely true of me, ‘2’: sometimes true of me, ‘3’: this item is true of me about half the time, ‘4’: frequently true of me. ‘5’: almost always true of me. [2] ‘1’: strongly disagree, ‘2’: disagree, ‘3’: neither agree, nor disagree, ‘4’: agree. ‘5’: strongly agree. [3] ‘1’: considerably less frequently, ‘2’: less frequently, ‘3’: as frequently as it did, ‘4’: more frequently. ‘5’: much more frequently.

Following these results, we explored the potential variances that may be also identified in the mapping of the lived complexity as experienced by the students of the two departments, in comparison with the one found for the whole population. The results of the analyses are summarised in Table 3 and Table 4.

With respect to the dynamic affect system about mathematics, in comparison to the whole population only one differences was found: the Mechanical Engineers’ pragmatic representation of respect did not statistically differ from the conceptual neutral. However, the results radically differ when focusing on the identified interlinking of the aspects of the affect system. In particular, the Mechanical Engineers seem to converge with the whole population, whilst the Electrical Engineers appear to experience a qualitatively different reality. For the Electrical Engineers, the interlinkings within the affect system appear to almost disappear.

*Table 3.*
*Learning mathematics and studying in ASPETE: a mapping of the lived complexity as experienced by the Mechanical Engineers.*

| | | *M* | *Mdn* | *P* | | *Deep*[8] | *Surface*[8] | *Confidence* |
|---|---|---|---|---|---|---|---|---|
| *Deep approach* | | 3.0[1] | 3.1 | 0.948[4] | | | | |
| *Surface approach* | | 2.6[1] | 2.6 | <0.001[4] | | | | |
| *Confidence in learning mathematics* | | 3.1[2] | 3.1 | 0.216[5] | *τ*[7] | 0.281 | -0.334 | |
| | | | | | *P* | 0.027 | 0.008 | |
| *Respect* | Pragmatic | 4.2[2] | 4.4 | 0.216[5] | *τ* | 0.119 | -0.003 | 0.284 |
| | | | | | *P* | 0.256 | 0.979 | 0.022 |
| | Desired/Intentioned | 3.3[3] | 3.1 | 0.002[6] | *τ* | 0.146 | -0.231 | -0.118 |
| | | | | | *P* | 0.181 | 0.034 | 0.406 |
| *Organisation* | Pragmatic | 3.4[2] | 3.1 | 0.002[5] | *τ* | 0.170 | -0.057 | -0.155 |
| | | | | | *P* | 0.109 | 0.589 | 0.300 |
| | Desired/Intentioned | 4.4[3] | 4.6 | <0.001[6] | *τ* | -0.034 | -0.129 | 0.278 |
| | | | | | *P* | 0.762 | 0.249 | 0.035 |
| *Challenge* | Pragmatic | 3.9[2] | 3.9 | <0.001[5] | *τ* | 0.147 | -0.069 | 0.379 |
| | | | | | *P* | 0.162 | 0.513 | 0.002 |
| | Desired/Intentioned | 3.4[3] | 3.7 | 0.001[6] | *τ* | 0.168 | -0.107 | -0.128 |
| | | | | | *P* | 0.127 | 0.329 | 0.357 |
| *Conceptions* | Number/Components | 3.6[2] | 4.0 | <0.001[5] | *τ* | 0.131 | -0.008 | -0.004 |
| | | | | | *P* | 0.309 | 0.950 | 0.971 |
| | Modelling/Abstract | 4.0[2] | 4.0 | <0.001[5] | *τ* | 0.165 | 0.191 | 0.338 |
| | | | | | *P* | 0.210 | 0.145 | 0.004 |
| | Life | 3.3[2] | 3.2 | 0.009[5] | *τ* | 0.033 | -0.155 | 0.289 |
| | | | | | *P* | 0.800 | 0.230 | 0.013 |
| *Studies* | Practical | 3.8[2] | 3.8 | <0.001[1] | *τ* | 0.035 | 0.099 | 0.299 |
| | | | | | *P* | 0.789 | 0.442 | 0.011 |
| | Generic | 3.4[2] | 3.5 | 0.001[1] | *τ* | 0.004 | 0.096 | 0.259 |
| | | | | | *P* | 0.975 | 0.460 | 0.025 |
| | (lack of) Knowledge | 3.6[2] | 3.7 | <0.001[1] | *τ* | 0.152 | 0.181 | 0.277 |
| | | | | | *P* | 0.251 | 0.171 | 0.019 |
| *Career* | Practical | 3.7[2] | 3.6 | <0.001[1] | *τ* | 0.013 | 0.130 | 0.309 |
| | | | | | *P* | 0.923 | 0.321 | 0.009 |
| | Generic | 3.2[2] | 3.3 | 0.065[1] | *τ* | 0.034 | 0.104 | 0.331 |
| | | | | | *P* | 0.790 | 0.416 | 0.004 |
| | (lack of) Knowledge | 3.3[2] | 3.4 | <0.001[1] | *τ* | 0.075 | 0.183 | 0.207 |
| | | | | | *P* | 0.561 | 0.154 | 0.077 |

[1] '1': never or rarely true of me, '2': sometimes true of me, '3': this item is true of me about half the time, '4': frequently true of me. '5': almost always true of me. [2] '1': strongly disagree, '2': disagree, '3': neither agree, nor disagree, '4': agree. '5': strongly agree. [3] '1': considerably less frequently, '2': less frequently, '3': as frequently as it did, '4': more frequently. '5': much more frequently. [4] One-sample Wilcoxon signed rank test to the hypothesised median "3": "this item is true of me about half the time". [5] One-sample Wilcoxon signed rank test to the hypothesised median "3": "neither agree, nor disagree". [6] One-sample Wilcoxon signed rank test to the hypothesised median "3": "as frequently as it did". [7] Kendall's tau τ non-parametric correlation. [8] 'Deep': Deep approach, 'Surface': Surface approach, 'Confidence': Confidence in learning mathematics.

*Table 4.*
*Learning mathematics and studying in ASPETE: a mapping of the lived complexity of as experienced by the Electrical Engineers.*

| | | *M* | *Mdn* | *P* | *Deep*[8] | *Surface*[8] | *Confidence* |
|---|---|---|---|---|---|---|---|
| *Deep approach* | | 3.0[1] | 3.0 | 0.837[4] | | | |
| *Surface approach* | | 2.5[1] | 2.5 | <0.001[4] | | | |
| *Confidence in learning mathematics* | | 3.5[2] | 3.5 | 0.002[5] | 0.281 | -0.334 | |
| | | | | | 0.027 | 0.008 | |
| *Respect* | Pragmatic | 4.1[2] | 4.3 | <0.001[5] | 0.119 | -0.003 | 0.133 |
| | | | | | 0.256 | 0.979 | 0.295 |
| | Desired/Intentioned | 3.3[3] | 3.0 | <0.001[6] | 0.146 | -0.231 | -0.036 |
| | | | | | 0.181 | 0.034 | 0.791 |
| *Organisation* | Pragmatic | 4.2[2] | 4.4 | <0.001[5] | 0.170 | -0.057 | 0.167 |
| | | | | | 0.109 | 0.589 | 0.193 |
| | Desired/Intentioned | 3.3[3] | 3.0 | <0.001[6] | -0.034 | -0.129 | -0.028 |
| | | | | | 0.762 | 0.249 | 0.838 |
| *Challenge* | Pragmatic | 3.9[2] | 3.9 | <0.001[5] | 0.147 | -0.069 | 0.163 |
| | | | | | 0.162 | 0.513 | 0.204 |
| | Desired/Intentioned | 3.3[3] | 3.0 | <0.001[6] | 0.168 | -0.107 | 0.117 |
| | | | | | 0.127 | 0.329 | 0.383 |
| *Conceptions* | Number/Components | 3.8[2] | 3.8 | <0.001[5] | 0.131 | -0.008 | 0.138 |
| | | | | | 0.309 | 0.950 | 0.281 |
| | Modelling/Abstract | 3.9[2] | 4.3 | <0.001[5] | 0.165 | 0.191 | 0.210 |
| | | | | | 0.210 | 0.145 | 0.110 |
| | Life | 3.3[2] | 3.3 | 0.008[5] | 0.033 | -0.155 | 0.041 |
| | | | | | 0.800 | 0.230 | 0.752 |
| *Studies* | Practical | 3.9[2] | 4.0 | <0.001[1] | 0.035 | 0.099 | 0.085 |
| | | | | | 0.789 | 0.442 | 0.510 |
| | Generic | 3.6[2] | 3.5 | <0.001[1] | 0.004 | 0.096 | 0.069 |
| | | | | | 0.975 | 0.460 | 0.593 |
| | (lack of) Knowledge | 4.0[2] | 4.0 | <0.001[1] | 0.152 | 0.181 | 0.198 |
| | | | | | 0.251 | 0.171 | 0.134 |
| *Career* | Practical | 3.8[2] | 4.0 | <0.001[1] | 0.013 | 0.130 | 0.175 |
| | | | | | 0.923 | 0.321 | 0.184 |
| | Generic | 3.3[2] | 3.3 | 0.002[1] | 0.034 | 0.104 | 0.078 |
| | | | | | 0.790 | 0.416 | 0.542 |
| | (lack of) Knowledge | 3.6[2] | 3.4 | <0.001[1] | 0.075 | 0.183 | 0.195 |
| | | | | | 0.561 | 0.154 | 0.128 |

[1] ‘1’: never or rarely true of me, ‘2’: sometimes true of me, ‘3’: this item is true of me about half the time, ‘4’: frequently true of me. ‘5’: almost always true of me. [2] ‘1’: strongly disagree, ‘2’: disagree, ‘3’: neither agree, nor disagree, ‘4’: agree. ‘5’: strongly agree. [3] ‘1’: considerably less frequently, ‘2’: less frequently, ‘3’: as frequently as it did, ‘4’: more frequently. ‘5’: much more frequently. [4] One-sample Wilcoxon signed rank test to the hypothesised median “3”: “this item is true of me about half the time”. [5] One-sample Wilcoxon signed rank test to the hypothesised median “3”: “neither agree, nor disagree”. [6] One-sample Wilcoxon signed rank test to the hypothesised median “3”: “as frequently as it did”. [7] Kendall’s tau τ non-parametric correlation. [8] ‘Deep’: Deep approach, ‘Surface’: Surface approach, ‘Confidence’: Confidence in learning mathematics

The main cause of this difference seems to be the fact that confidence was not statistically significantly correlated with any other aspects of the system. Moreover, these students were found to be borderline positive about their confidence in learning mathematics and strongly positive about their desire for organisation. It is posited that being on the positive of the confidence spectrum allows for the students to experience differently the diverse aspects of the dynamic affect system about mathematics. However, non-positive confidence seems to act as a crucial attractor within the dynamic affect system about mathematics, in the sense that it is positively correlated with multiple aspects of the system. Recall (see Table 2) that the Mechanical Engineers, in comparison with the Electrical Engineers, were statistically significantly less satisfied by their pragmatic representation of the experienced mathematics teaching and statistically significantly desiring more organisation, whilst no statistically significant differences between the two departments were identified in the broader experience in ASPETE. Consequently, since different lecturers were teaching in the two Departments, it is hypothesised that the diverse mathematics teaching practices may also be linked with the identified differences.

## 5. DISCUSSION AND CONCLUDING REMARKS

In this paper, we discussed a multileveled affective mapping of the complex lived reality that the first year Electrical Engineers and Mechanical Engineers of ASPETE experience with respect to mathematics. We adopted a systemic approach to include in our investigations the broader experience about studying in ASPETE. We proposed a dynamic affect system, including confidence in learning mathematics, their conceptions about mathematics and its role in their studies and career, and their views about mathematics teaching effectiveness (considering both what they actually experienced and what they would prefer to experience).

The results of the conducted analyses in general accorded with and, at the same time, enriched previous studies. First, in line with previous studies, the ASPETE students showed a lack of preference for the surface approach (though not combined with a preference for a deep approach) and they considered mathematics as being mainly about models and techniques (Moutsios-Rentzos, & Kasimati, 2014; Kasimati et al, 2016). Moreover, we added to previous results (Maass, & Engeln, 2019; Wood et al, 2012) the fact that the ASPETE engineering students expressed a neutral-positive confidence in learning mathematics, and they appeared to be satisfied with the actual mathematics teaching, identifying area for improvement.

Furthermore, our systemic approach allowed for investigations both within the mathematics dynamic affect system (cf. Pepin, & Roesken-Winter, 2014) and, importantly, between the mathematics-specific and the broader ASPETE experience. Considering the mathematics affective relationships, the students' conceptions about mathematics seemed to be related with the desired characteristics of mathematics teaching. However, it was the students' confidence in learning mathematics that appeared to be the crucial element of our dynamic affect system, as it was linked with most of the other aspects. In addition, confidence appeared to be also the main link between the broader and the narrower level of experience, as it was statistically significantly negatively correlated with a surface approach.

Our further systemic explorations acknowledged the existence of two distinct, yet inter-related, subsystems within the ASPETE system, with respect to the degree that the students followed: Electrical or Mechanical Engineering. Our analyses revealed a more complex reality. On the one hand, the students shared a similar experience of ASPETE as an educational unit, thus suggesting their belonging to a common educational system. On the other hand, they differed only in their degree of confidence in learning mathematics and in their representations about mathematics teaching, signifying their sub-system differentiation. Our systemic approach focusses on affective relationships that form the dynamic affect system, which revealed that the students of the two departments experienced a qualitatively different affective complexity. Notably, the role of confidence appeared to be crucial in the characteristics of the affective system. Moreover, mathematics as a subject taught has a diverse presence in the ASPETE system and its subsystems, as the acting and interacting protagonists assuming their dynamic roles are engaged in the teaching and learning of mathematics. For example, it is hypothesised that mathematics may be a subject taught with a similar content taught in both departments, but the nature of departmental affiliation (Bingolbali et al., 2007) and/or the students' complex, interdisciplinary professional identity (including potentially both practicing engineers and teachers; Garner, & Kaplan, 2019) may crucially affect the way that mathematics teaching effectiveness is conceptualised and experienced. Moreover, potential links of confidence with organisation of teaching appeared to render further investigations to be conducted.

Following these, it is argued that the proposed approach accords with the existing findings, allowing at the same time to *meaningfully* extend these investigations to include further relationships and inter-relationships. Consequently, within the broader research project (MATHETE) we focus on systemic investigation about teaching and learning mathematics in ASPETE, including investigations about the role of teaching practices, departmental affiliation, as well as about the potential temporal developments in the aforementioned phenomena.

Though our approach has been implemented only in the ASPETE educational system, we argue that our approach may pragmatically and substantially contribute to the improvement of mathematics teaching in ASPETE, but also in other engineering education systems. This approach may be implemented in other tertiary educational units complementing other efforts for modern mathematics education in engineering education (Aditya, & Olds, 2014; Pohjolainen, Myllykoski, Mercat, & Sosnovsky, 2018), by explicitly acknowledging the importance of the identification and incorporation in the educational planning, the peculiarities of the specific educational system, its subsystems and its environment.

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