Implementing Constructive Alignment Theory in a Power System Analysis Course using a Consensus Model

Luigi Vanfretti and Mostafa Farrokhabadi
Electric Power Systems Department
KTH Royal Institute of Technology
Stockholm, Sweden
luigiv@kth.se, mostafaf@kth.se

Abstract— **This article presents a consensus-based course design process which considers the implementation of constructive alignment theory (CAT) in a power system analysis course. A new concept for course design which uses the consensus decision-making process involving different stakeholders in the learning process is exposed, and the considerations required to implement this approach in a power system analysis course are described. To examine the effect of this approach, three different course evaluations were conducted by querying the students during different stages of the course. These evaluations show that most of the students find a benefit for their learning in the implementation of CAT within the new course design. These observations are supported by a comparison of the students' performance with the new course design with an antecessor course. Finally, the Two-Factor Study Process Questionnaire (R-SPQ-2F) was utilized to identify the students that adopted a deep or surface approach during the course. During this process, several limitations which affect the quality of the results from the R-SPQ-2F questionnaire were identified. In view of these limitations, and to extract relevant information from R-SPQ-2F, a ranking algorithm was developed. This information helps selecting relevant student feedback which can be used to improve the course design in subsequent deliveries.**

Keywords- Power System Analysis; Constructive-Alignment Theory; Two-Factor Study Process Questionnaire

I. INTRODUCTION

In non-engineering fields such as medicine and public health, consensus-based educational frameworks have been developed to address the needs stipulated by professional associations. Through the consensus process, working groups have been created to determine the competency set which educators can use to develop intended learning outcomes for courses in the study programs available for professionals working in this field [1]. For the engineering discipline, such sorts of competence have been developed and continue to be revised in the USA, Europe and Latin America [2], [3], [4]. Defining this kind of competence sets are a crucial for developing curriculum frameworks such as those developed in Australia and Asia [5], which assemble groups of stakeholders that deliver specifications or standards describing a competence set for pre-college studies. This approach can move the traditional education system to have a more systematic way of defining curriculum. For higher education, the key element for achieving this as seen in the case in [1] is the use of forms of consensus, which include different stakeholders, in the curriculum design.

The most relevant stakeholders in the educational system are of course students. For the engineering discipline, and particularly electric power engineering, it is not clear if student involvement exists in the consensus process that determines and redefines the core competence sets which students should achieve [3]. This is puzzling because students are the ones who will be affected the most by the decisions taken in the design of their education, and therefore their views should be considered in a more integrated manner in course design. There is good evidence supporting why it is relevant to have increased student involvement in designing engineering courses [6].

This article argues for student involvement through the consensus-oriented decision making (CODM) model [7]. Using this model, it proposes a consensus-based implementation of constructive alignment theory (CAT) in a power system analysis course. This forms a new methodology for course design which uses the form of consensus with different stakeholders in the learning process is exposed, and the modifications required to implement this approach in a power system analysis course are described.

To examine the effect of this approach for CAT implementation and course design, three different course evaluations were conducted by querying the students during different stages of the course. These evaluations show that most of the students find a benefit for their learning in the implementation of CAT within the new course design. These observations are supported by the comparison of the students' performance with the new course design as compared to the anteceding course.Finally, the Two-Factor Study Process Questionnaire (R-SPQ-2F) was utilized to identify the students that adopted a deep or surface approach during the course. During this process, several limitations which affect the quality of the results from the R-SPQ-2F questionnaire where identified. In view of these limitations, and to extract relevant information from R-SPQ-2F, a ranking algorithm was developed that help selecting relevant student feedback that can be used to improve the course design in subsequent deliveries.

II. CONSENSUS-BASED IMPLEMENTATION OF CONSTRUCTIVE ALIGNMENT THEORY

A. Background

The course which served as a research platform in this study is "EG2021 Power Systems Part 1" (EG2021), offered by the Electric Power Systems Division of KTH Royal Institute of

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Technology, Sweden. This is a 7.5 credit M.Sc. level course that provides an introduction to electrical power networks and methods for their analysis.

The course is a (compulsory) foundational cornerstone in the first period for studies in different M.Sc. study programs including Electric Power Engineering (TELPM), and more importantly, the Smart Electrical Networks and Systems (SENSE) M.Sc. joint program. In addition, within KTH, the course is also elective in other M.Sc. programs at the School of Electrical Engineering and several Erasmus Mundus M.Sc. programs where KTH participates.

As it can be noticed from above, the course has to cater to students arriving with different cultural and academic backgrounds, a broad age spectrum, diverse professional orientations, and (miss)pre-conceptions about the course. It is therefore not an easy task to design a course that offers the right learning environment to serve such a broad student base.

EG2021 has an antecessor course "EG2020 Power Systems, Basic Course" (EG2020) serving relatively the same M.Sc. programs and similar content. The Electric Power Systems Department of KTH Royal Institute of Technology decided that this course should be changed, thereby EG2021 was created and the contents where determined prior to a formal course design. However, instead of latching on to the traditional structure of EG2020 (which is shared with other courses offered at the same Division), the course and its learning environment were completely re-designed into a new format.

The authors decided to move the course into a format that adapted to constructive alignment theory. To do this, a consensus-based decision making process was used for the course design, as explained next.

B. *Consensus-Based Course Design*

Through history, there have been several models for consensus-based decision making, most notably the Quaker model [8]. The term consensus must not be misinterpreted as "unanimity", it is used here to refer to a "general agreement" [9]. For course design a collaborative consensus-decision making process is necessary to attain the commitment of the design group for a successful implementation. The consensus-based course design here consists on the adoption of a consensus model, the construction of a design group and the elaboration of a design through a design process. These aspects are discussed next.

1) Consensus model – The consensus-oriented decision making (CODM) model [7] was used and *adapted* to develop a new course design. In [7] a seven step process is defined, the process gives the opportunity to involve all the stakeholders in the decision group (design group in this case) in an active manner. This results in a shared proposal in which all the concerns of the group members are considered as much as possible. This model is appropriate for course design because it accommodates for the case when the actual decision is made by the person in charge (the faculty in this case) – to achieve this, the design process and the resulting shared design must be respected by the authority figure to guarantee the engagement of the design group. This is important as the design group was also involved in the development and implementation of the teaching and learning activities.

2) Design group – The design group (or decision group) was initially intended to consider a broad spectrum of stakeholders, such as representatives from industry and university administrators, but these declined the invitation to participate. With this limitation, the design group was then restricted to students and faculty, and its focus was set up to gather a broad amount of student views regarding the course to be designed. Faculty was represented by the course examiner (the first author of this paper), which took a role of a facilitator. The group included two former MSc students that have taken the previous course (EG2020), one of which was a student attaining average marks in his courses and the second was a top student of the TELPM MSc programme. This allowed considering the issues that different student types might rise.

The design group also included two PhD students, one that graduated from the TELPM MSc programme and had been a student of EG2020 himself, and had also served as a Teaching Assistant for EG2020, and another PhD student that came from another institution.

During the design process it was determined that the group encompassed balanced and broad population of students to cover all of the possible issues affecting student learning as seen from the student perspective. Also, the facilitator offered enough experience from the faculty perspective.

3) Design process (decision making process) - With CODM model the participants of the "design group" contributed to a shared proposal, everyone in the group was involved in developing a shared course design – this gave the involved students a sense of ownership. This commitment was important to attain because it was envisioned that the members of the design group would also take part in the implementation of the design. The design was carried out in five different sessions of about two hours each (10 hrs.) during June and July 2011. The course was delivered from late August to early October, 2011. The steps in the CODM model where not repeated in each session; instead the meetings follow the method step by step through the meetings until the design was completed.

Step 1: Framing the Problem – During the first meeting the facilitator gave the students an explanation of CAT and reasons to adopt a consensus-based approach to the course design. To frame the problem more specifically, the facilitator expressed the different pre-requisites and post-requisites that the design needed to take into account and support the course ILOs.

Next, the facilitator proposed different T&L activities and assessment options; emphasis was made that the selection of T&L and assessment should consider principles from CAT.

Furthermore, a design rule was created by the design group using Cause-and-Effect Analysis [10] relating the T&L and Assessments to the ILOs. The design rule is illustrated in Fig. 1 for the "Weekly Tests" T&L Activity.

Step 2: Open Discussion – After Step 1 was completed, an open discussion took place to determine which T&L activities

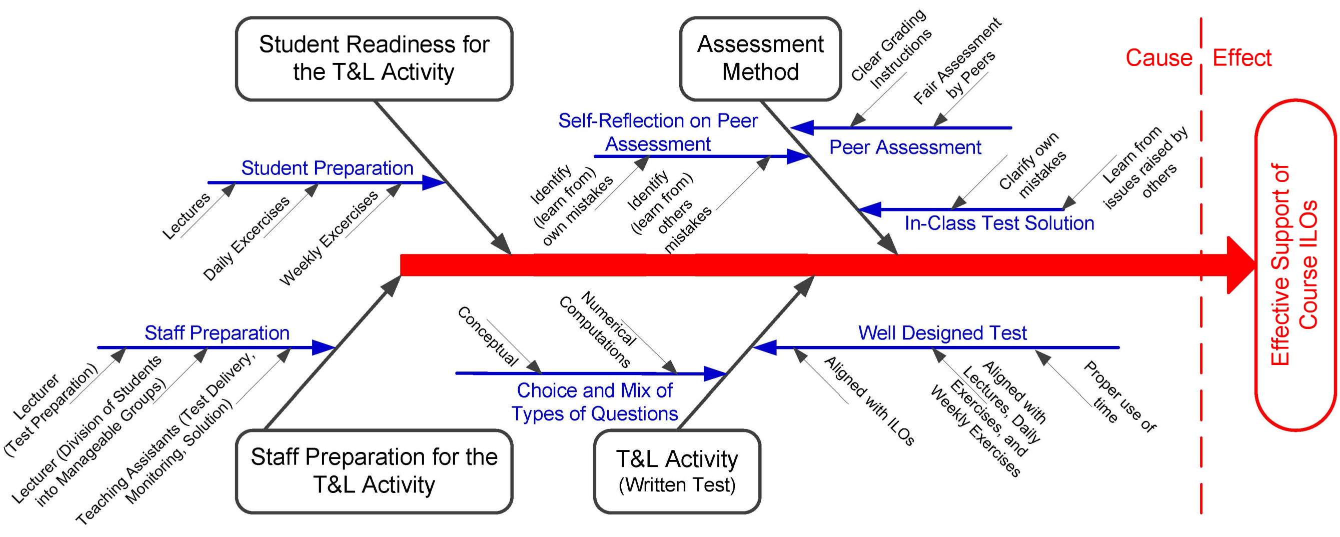

Fig. 1. Fishbone Diagram integrating the rule for implementing CAT - Example for the “Weekly Tests” T&L Activity

the course should consider using the spoken version of the Round-Robin Brainstorming Technique [11].

Step 3: Identifying Underlying Concerns – Underlying concerns are constraints that are need to be meet and problems that might arise with the preliminary course design selected. In this case, it was necessary to identify the constraints and problems that would affect how effective each of different T&L activities would be to support the students in reaching the ILOs, these includes “time constraints to accommodate different T&Ls”, “possible occurrence of plagiarism and the effective use of computer programs”, “human resources to carry out the course implementation”, and “fairness of the assessment methods”.

Steps 4 & 5: Developing Proposals and Choosing a Direction –The group was encouraged to bring forward proposals to mitigate the underlying concerns identified in Step 3. To achieve this each of the T&L activities where studied individually, and as a whole. A holistic assessment was made to streamline the course design, and the decision rule in Step 1 was used to change or eliminate T&L or assessment activities. As a result, several T&L activities where taken out of the course design; an assessment method satisfying underlying concern for above were developed.

After this process was completed, the final course design presented in Section II-C was achieved. A rationale on how each T&L and assessment activity support the ILOs is given in Section II-C.

Step 6: Developing a Preferred Solution – This step looks on how the final course design could be improved further. To this aim, the design group became concerned with more practical issues that it would face as the implementation group. For example, one of the modification made was on the T&L and assessment activity “[10] Weekly Tests and Weekly Test In-Class Solution” (see Section II-C.); to cater to constraint 3 the group decided the use of peer-assessment for the marking of the tests.

Step 7: Closing – The designed course was put into scrutiny one more time with the design group. The decision rule developed in Step 1 was used to evaluate each of the T&L activities and the course assessment to ensure that there was consensus to move forward with the implementation.

C. CAT Implementation

Constructive Alignment Theory is comprised by a set of principles that can be used to devising Teaching and Learning Activities (T&Ls) that help in achieving the Intended Learning Outcomes (ILOs). This is accomplished by carefully aligning T&Ls and learning assessments to support the students to fulfill the ILOs. For a comprehensive exposure of CAT the reader is referred to [12], while an example of the implementation of CAT in a course project and research activities in a power system analysis course is offered in [13].

A summary of the T&L activities and assessment that constituted the final CAT implementation and course design is provided below, we illustrate how these T&L and the course assessment aid the students’ in achieving the ILOs in Fig. 2.

1) Lectures: a total of 24 lectures that cover all the topics of the course.

2) Daily in-class Exercises: exercises were carried in the class room by each student using a multiple-choice answer sheet. Daily in-class exercises are not graded, and the aim is to motivate them to go through the lecture’s content before attending the class.

3) Weekly Exercises: Each week there was a set of exercises for the students to practice the methods and study the concepts covered during the lectures of that week. No points are awarded for these exercises. The exercises are aimed to prepare the students for the weekly tests.

4) Weekly Tests and Weekly Test In-Class Solution: There were a total of 6 weekly tests, they accounted for 50% of the final grade. For the final grade 5 out of 6 tests with the highest grade were counted.

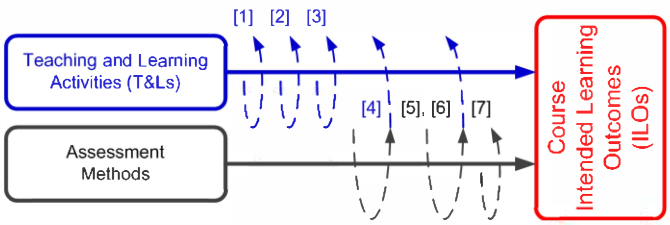

Fig 2. Final Course Design with a CAT Implementation supporting the course ILOs. The numbers in brackets refer to the T&L Activities and Assessment Methods Described Below

5) Grading of the weekly tests: After the test is finished, the problem sheets and answer sheets were distributed among all students, which will check the other student's test using a key provided by the Teaching Assistants. The Teaching Assistants double checked the grades assigned to the students.

6) Weekly Test In-Class Solution: After the tests were graded, the Teaching Assistants stayed with interested students only to solve each of the problems in the weekly test.

7) Final Exam: The final examination accounts for 50% of the final grade. The final exam is a single-part examination with problems similar to those solved in the Weekly Exercises and Weekly Tests.

TABLE I. Grading Scale for Students' Learning Assessment

Total Points Final Exam + Weekly Tests	Grade Letter
91 – 100	A
84 – 90	B
76 – 83	C
69 – 75	D
61 – 68	E
58 – 60	FX
00 – 60	F

Overall Assessment – A grade letter is awarded to the students according to Table I.

D. Analysis on the Effect of the Implementation of CAT through Consensus-Based

There were three course evaluations, two between tests and one during the final evaluation – due to space limitations the evaluations are not described here. For each evaluation the following number of students replied:

- Evaluation 1: 66 (10 were enrolled in the old course).
- Evaluation 2: 62 (10 were enrolled in the old course).
- Evaluation 3: 62 (9 were enrolled in the old course).

Students registered that were enrolled in the anteceding course EG2020 where asked the following questions:

- Fig. 3: Is the new course structure (lectures, daily exercises, weekly exercises, and weekly tests) preferable to the previous course structure (lecture, assignments, and final examination)?
- Fig. 4: Is the new course grading structure in EG2021 (50% weekly tests + 50% final examination) more preferable than the previous course grading (part a and part b)?
- Fig. 5: Overall, are you more satisfied or less satisfied with the new course compared to the previous course?

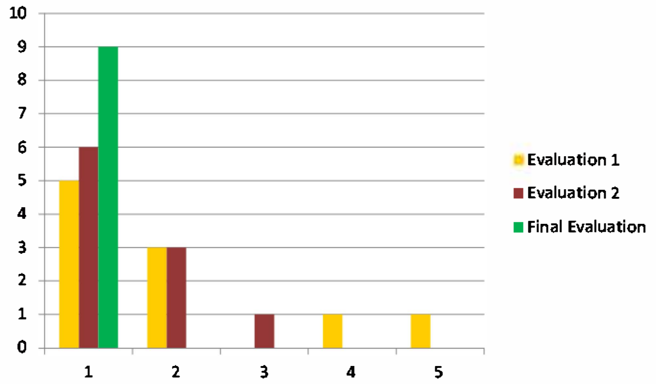

Fig. 3. (x-axis: no. of students, y-axis: 1-Strongly Agree, 5-Strongly Disagree)

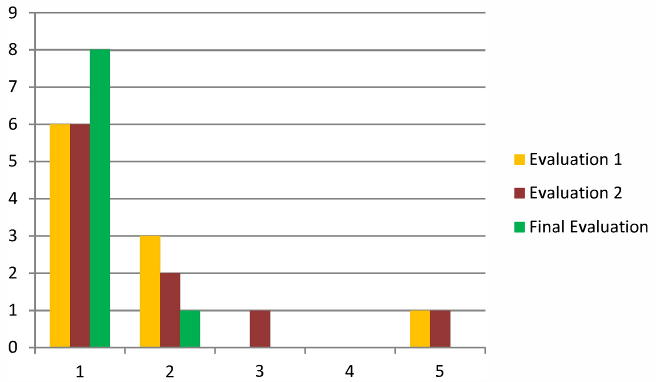

Fig. 4. (x-axis: no. of students, y-axis: 1-Strongly Agree, 5-Strongly Disagree)

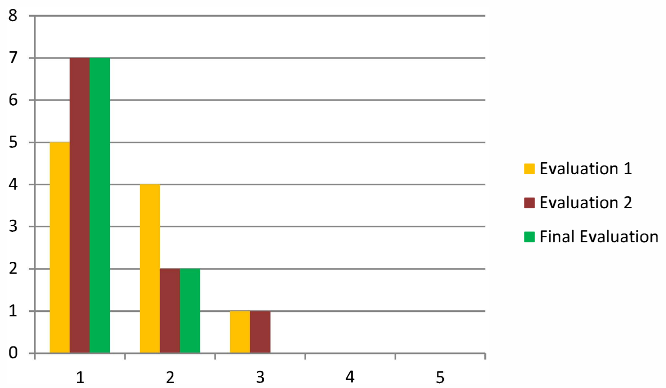

Fig. 5. (x-axis: no. of students, y-axis: 1-Strongly Agree, 5-Strongly Disagree)

Figures 3-5 show an interesting effect. Initially there was some opposition of the students to the new course design; however this perception changed through time. The change in perception (shown in Fig. 3) shows that the course T&L activities are better aligned to support the ILOs than in the previous course. The ratings given by the students reach the highest satisfaction level after the final evaluation, which supports this claim. Moreover, it can be observed that the assessment method is well aligned in EG2021 with the T&L activities and support the ILOs in contrast with EG2020. Figure 4 supports this statement; the evaluations of the students give a higher rating to the course assessment structure as the evaluations are carried out reaching almost a full satisfaction by the final evaluation.

This is a good indicator that the course design has properly addressed the shortcomings of the previous course. To verify this, it is possible to see the time progression of the students "rating" of the course as a whole, for all of the students that replied to the questionnaire. As shown in Fig. 6, the students rating of the course improved through time, ratings at 3 (Acceptable) declined as the evaluations progressed, while ratings at 1 (Excellent) increased significantly during the final evaluation. Moreover, during the evaluations very few students evaluated the course as 4 (Bad) and 5 (Poor), with a maximum of 6.4% at 4 (Bad) for the final evaluation.

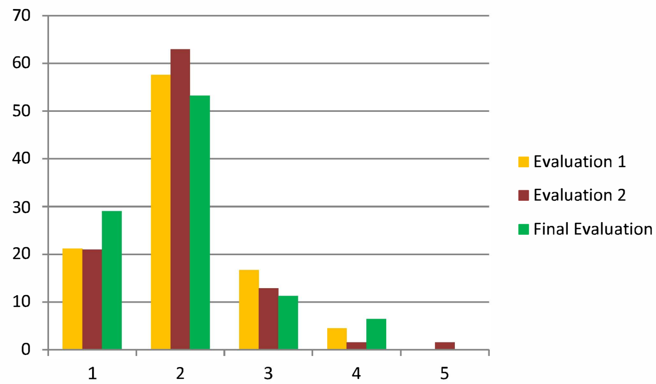

Fig. 6. Rating of the course as a whole. (x-axis: % of students, y-axis: 1-Ecellent, 5-Poor)

Figure 7 shows the grade distribution for the new course given in 2011, and the previous version of the course given in 2010, 2009 and the average results for years 2007-2010. It is noted that there is an even distribution between grades A, B and C. this is viewed as a positive effect; grades are not clustered in B, C and F. In the previous course the grade distribution was 9% A's, 18% B's, 31% C's and 5% of D's and E's, with more than 31% F's. With the new course, a more even distribution is achieved, with grades A to C around 19%.

However, it was expected that the final course grade distribution would include a higher distribution of grades around the higher ratings (A, B and C). It is speculated that this was due to a major drawback in the course design – preliminary analysis shows that the final exam was not design

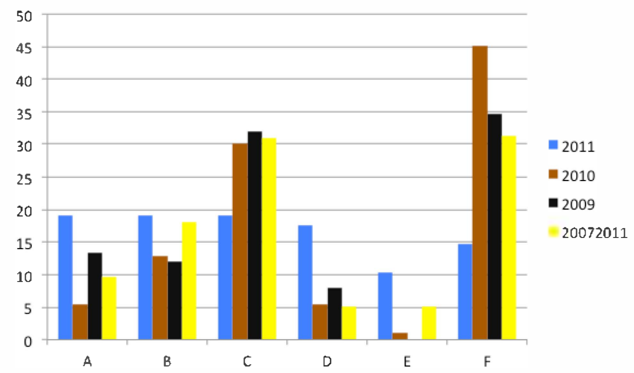

Fig. 7. Grades distribution (A: 91-100, B: 85-90, C: 76-83, D: 69-75, E: 61-78, Fx: 58-60, F: 0-57)

properly to generate the expected outcome. It is conjectured that students adopting a surface approach were still able to attain high marks; this conjecture is investigated in another publication [14].

III. Correlations between Students' Learning Approaches and Assessments Results in the Consensus-Based Course Implementation

It is quite important to incessantly modify the course design to align it to the course ILOs. To achieve this, it is necessary not only to gather students' feedback, but also to identify most relevant ones and properly address them.

This may seem like a simple task, however, to do this systematically it is necessary to use tools for identifying relevant feedback. For a proper implementation of CAT, it is necessary to determine what needs to be improved in the course to support not only "deep learners", but also those adopting the "surface" approach. This section investigates a technique to properly classify the "students' approach depth".

A. Obtaining Empirical Data

During the final evaluation, a new section was introduced where the Two-Factor Study Process Questionnaire (R-SPQ-2F) was utilized [15]. R-SPQ-2F is a recognized tool that allows determining the learning approach by students. The analysis of the R-SPQ-2F questionnaire will allow selecting students from each category of "deep" or "surface" very wisely to conduct further interviews. The approach to the interviews is recommended in an article by Thota [16] where a repertory grid is used to extract both quantitative and qualitative information. This approach allows for triangulation with the data from the course evaluations also.

B. Limitations of the R-SPQ-2F Questionnaire

R-SPQ-2F technique provides a basic classification method. The students assign a grade to each question on the questionnaire from 1 to 5. The idea is that there are two types of questions, those which are related to the deep approach (Type 1), and those which are related to the surface approach (Type 2). Students have no clue about each questions' "type", as they are ordered randomly, however some of the questions have an obvious "motive". For each student, the scores of the questions in same type are added together. The results are interpreted in the way that the student with the highest grade from the summation of Type 1 questions is known as the students with the deepest approach, while the student with the highest grade on Type 2 questions is probably the one with the most surface approach. However, there is a problem with this strategy. The problem is that it is very hard to design the questions in a way that the students can't understand to which type each question belongs. This may have harmful effects on the final results of the traditional R-SPQ-2F.

C. A ranking routine for extracting relevant information from R-SPQ-2F

Another important defect of R-SPQ-2F is illustrated in Fig. 8. After scrutinizing the results, it was revealed that a large number of students had similar scores for both question types – ranking almost as high in DA (deep approach) as in SA (surface approach). Note for example that the first three students have the same score for both categories.

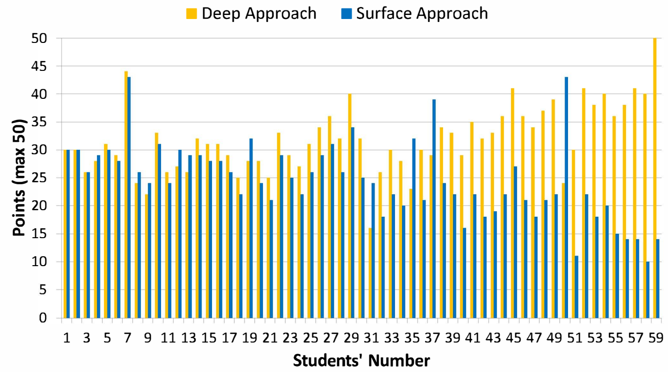

Fig. 8. R-SPQ-2F Scores

To eliminate the effect of this phenomenon in the final students' "approach depth" ranking, and to mitigate the shortcomings of the questionnaire listed above, a ranking algorithm was developed. Each student has been assigned two ranks, one for DA and one for SA. Then these ranks are used as weighting factors. Next the students have been assigned a final rank using equation 1. The higher a student get from (1), the higher his rank is. Obviously, the student with the highest rank has the deepest approach (Fig. 9).

$$(Grade \times Rank)_{DA} - (Grade \times Rank)_{SA} \quad (1)$$

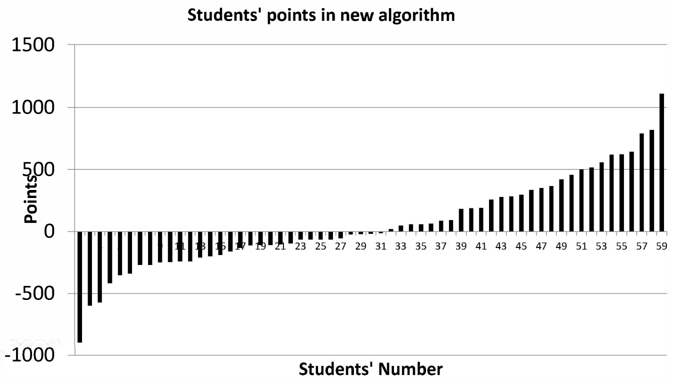

Fig. 9. Results of applying new ranking algorithm

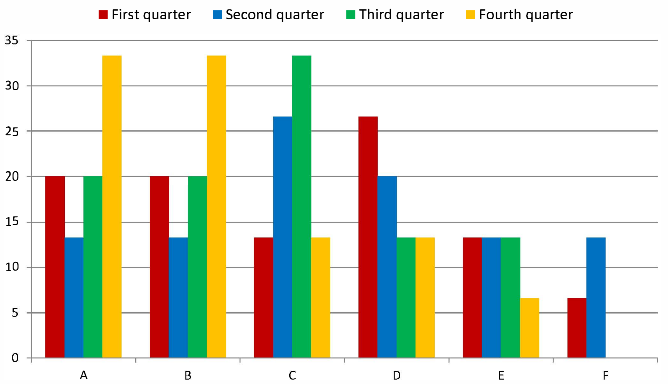

Fig. 10. Grade distribution and its correlation with subclasses of deep and surface learning. (y-axis: % for each quarter)

There is also a very fascinating chart related to the grade and final "approach depth" correlation (Fig. 10). The students are divided into 4 groups (each group consists of 25% of the students) based on their approach depth, the 25% with the lowest approach depth (first quarter), the second 25% with the lowest approach depth (second quarter) and so on. Please note that there is a strong correlation between the grades that the students have attained, and their corresponding approach depth.

IV. Conclusion

This article proposes the idea of consensus-based course design, where all the stakeholders in the learning process can be taken into account to shape the design of a course. Although in this study the consensus process has only considered a small set of stakeholders (mainly students), the process can perfectly adapt to include other stakeholders which are interested in participating. The results shown in this document on the implementation of constructive alignment theory into a power engineering course are good indicators that CAT is a good vehicle to enhance student learning. The remaining question is how the consensus-based course design needs to be modified so that students using the surface approached are moved into the deep approach. Further data analysis of repertory grid interviews provides such insight (Vanfretti and Farrokhabadi 2012).

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