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Effects of inquiry, computer simulation, and cooperation with intergroup competition on electrical engineering students

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ABSTRACT

Background: Undergraduate electrical-engineering courses are traditionally taught using the lecturing approach. As for all the teacher-centered approaches, the students perceive learning as an individualistic task and consider lecture-notes their principal information source. They tend to employ the minimum possible efforts to get acceptable marks and compete against other students for best scores. Learning theories considers learner-centered approaches, such as, inquiry, computer simulation, self-directed learning, cooperation and competition, valuable alternatives to the traditional lecturing approach.
Purpose: This study aims to develop, apply, and assess a new teaching approach to teach electric filters. The new-approach aims to improve the electrical engineering students learning outcomes and achievement, learning autonomy, and students perception of the role of engagement and cooperation in learning.
Sample: Sixty-four students voluntarily participated in the study. Thirty-two students voluntarily decided to participate in the new learning approach study-group, whereas the others played the role of the control-group and followed the traditional-teaching method.
Design and methods: The design of the new-approach combines inquiry, computer simulation, and cooperation with intergroup competition. The new-approach is developed in two phases. In the first phase, the preparation phase, the students learned electric filters using simple inquiry, cooperation, and learned and applied computer simulation in filter analysis. The second phase was a face-to-face debate on filters. Data was collected using pre-tests, post-tests, questionnaires, direct observation, and student portfolios. Independent and paired T-tests were used to verify the study hypothesis.
Results: The findings showed that, the student could learn autonomously. The new method improved the students learning outcomes and achievements. It also improved the electrical engineering students' perception of the role of engagement and cooperation in learning.

KEYWORDS
Intergroup-competition; electric filters; jigsaw; autonomous learning; simulation

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Conclusions: The study showed that, following the new-approach improved the tackled electrical engineering students' characteristics and defeated some of the negative effects of the traditional lecturing. This leads to think that a long-term implementation of the proposed approach can provide the students with the essential attitudes and skills that serve their future as electrical engineering professionals.

Introduction

Electrical engineers have to deal with complex problems and learn new theories and technologies. They also have to cooperate with their team members and to compete against other engineering teams. Several studies in the education literature at school and university levels showed that, the teaching strategies and tools have a great impact on students' values, attitudes and learning outcomes (Cheng-Huan and Chiung-Hui 2016; Baer et al. 2010; Yu 2001; Johnson and Johnson 2013). Therefore, the adoption of effective strategies in teaching electrical engineering courses can shape the characteristics and attitudes of the future engineers. Although many research studies were developed to determine the best teaching or learning methods, debates about this issue still very active. In fact, literature review on learning theories and education revealed that, there is an increasing interest in the impact of the active learning approaches on electrical engineering students (Korkmaz 2018; Verbic, Keerthisinghe, and Chapman 2017; Yadav et al. 2011).

The instructors of the electrical and computer engineering department at Birzeit University, as part of the electrical engineering education community, have always had active debates about the traditional-lecturing method, followed by all the staff of the department, and its effects on their students characteristics as learners. These debates always finished in a common sense agreement about several characteristics. They agreed on that, most of the students that follow the traditional-lecturing approach perceive their learning as an individualistic task. The students also believe that, their role is to follow the lectures taught by their instructors, study the lecture notes, and pass the course exams. The instructors also agreed on that the students tend to invest the minimum time and efforts necessary to achieve the scores they aim to. Moreover, they agreed on that most of the students that employ higher efforts do this because they compete with each other's to achieve higher scores, and that this competition prohibited the cooperation between the students. Furthermore, they agreed on that because of all these reasons the traditional-lecturing failed to provide the students with fundamental skills that enable them to be life-long learners. However, because of the fear of change and maybe other unknown reasons, the instructors continued to follow the traditional-lecturing approach.

Taking into account these facts and the common sense agreements, the authors decided to drop the lecturing method and expose their students to a learner-centered approach in teaching a part of the Electric Circuits II course, specifically, the electric filters. The Electric-Circuit II course is offered to the electrical engineering students. It is delivered, through three one-hour lectures per week, for 16 weeks. Additional six officehours per week are also programmed to respond to the specific needs of all the students enrolled in the instructors' courses. Usually, a small number of students make use of these hours and with a very low frequency. Thus, the interaction with and among the students occurs only during the lecture time and is limited to answering students' questions. The course is taught using a predefined textbook, its assessment is based on three traditional exams (first, second, and a final exams), besides to homework. The electric filters part is usually developed in four weeks.

The authors wanted to design a new teaching approach where the cooperation and the competition can coexist. The new-approach has to enhance cooperation and defeat the negative effects of competition. Moreover, the new-approach has to change the electrical engineering students' perception of the learning process as individualistic, instructor dependent, and that it requires shallow engagement. The authors wanted also to show that, the new-approach could improve the students learning outcomes and achievements. Therefore, the study hypothesis were that, the exposure of the students to the new-approach in learning electric-filters would foster their learning autonomy, improve their learning outcomes and achievement, foster their perception of the role of engagement in learning, and foster their perception of learning as a cooperative process. The new-approach has to answer the following questions:

(1) Can the new-approach improve the students learning outcomes and achievement?
(2) Can the new-approach improve the students learning autonomy?
(3) Can the new-approach improve the students' perception of the role of cooperation in learning?
(4) Can the new-approach improve the students' perception of engagement in learning?

The authors inspected the literature of the learning theories and education to select an appropriate method that tackle all these variables simultaneously; they found that, to answer the study questions, they have to use different active learning methods. The authors looked for a framework with which they can implement these learning methods. As a result of their search, the authors designed a new learning approach that uses inquiry, computer simulation, and cooperation with an appropriate and constructive intergroup competition. The intergroup competition was used for two objectives, the first is to foster the students' motivation in participating in the study activities, and the second is to use the intergroup competition as a framework where competition, cooperation, and other learning activities can be implemented contemporaneously. The theoretical foundation that dictated the authors' selection to use inquiry, computer simulation, cooperation, and intergroup competition in the design of the new-approach are presented in the following section.

Engagement and autonomy in learning

Several studies described engagement as a complex phenomenon that involves momentary interest and enjoyment to long-term abilities (Davis and McPartland 2012; Fredricks and McColskey 2012). Researchers found that, engagement harvests learning motivation and self-efficacy and thus improves students' achievement (Mason et al. 2013). Moreover, they found that it is related to both positive changes in skills, capabilities, and psychological adjustment during college years (Wilson et al. 2015). Therefore, developing activities that fosters students' engagement is one of the key objectives of active learning activities.

Researchers also stated that, engagement had different aspects that describe diverse behaviors, thoughts, perceptions, feelings, and attitudes. Engagement aspects were classified into emotional, behavioral, cognitive, and agentic (Renninger and Bachrach 2015; Reeve and Tseng 2011). Emotional engagement refers to feelings and attitudes about the learning task and context such as enjoyment, curiosity and anxiety. Behavioral, refers to learners' participation, effort, persistence, and concentration. Cognitive engagement refers to learners' investment in understanding and mastering the material. Finally, agentic engagement refers to the active contribution of the learner in the learning process. It occurs when the students are cooperatively involved with others (Davis and McPartland 2012). These engagement aspects are traditionally measured using self-reporting questionnaires, experience-sampling methods, direct observations and teacher rating, and video coding (Fredricks and McColskey 2012; Henrie, Halverson, and Graham 2015). In our study, we used direct observation and questionnaires.

In another context, electrical engineers need to learn the new and rapidly changing theories and technologies in their field. Learner-centered approaches are essential to provide the students with the required autonomous learning skills. In fact, the idea of such approaches is based on giving the students the opportunity to learn independently. Kember refers to autonomous learning as shifting the focus of education from teaching to learning (Kember 1997). Betts and Knapp define an autonomous learner as, 'one who solves problems or develops new ideas through a combination of divergent and convergent thinking and functions with minimal external guidance' (Betts and Knapp 1981). Holec describes autonomy as 'the ability to take charge of one's learning' (Holec 1981). Autonomous learner was also defined as a learner who asks appropriate questions, interrogates assumptions, and identifies resources and tools to achieve his learning goals (Warburton and Volet 2012).

However, learner autonomy does not mean his isolation from his learning environment, or that the teacher role becomes obsolete. In fact, Francom introduced four elements that emphasize the role of the teacher in fostering the student's self-directed learning skills (Francom 2010). Firstly, student readiness in terms of ability and motivation. Secondly, gradualism; that is, gradual reduction of the support and guidance of the teacher. Thirdly, integrality, which means introducing self-directed activities, promoting awareness, and using ad-hoc assessment tools to support learning autonomy (Guglielmino 2013). Finally, authenticity that means using real-world relevant tools and tasks. Thus, the teacher must develop learning activities that smoothly shift the learning control to the students. Such activities can be based on cooperation, inquiry, and computer-supported learning (Warburton and Volet 2012; Malan, Ndlovu, and Engelbrecht 2014).

Role of cooperation and competition in learning

Early studies, in pedagogy and psychology, showed that the appropriate use of cooperative, competitive, and individualistic methods is necessary to simultaneously promote high achievement, effective socialization, and healthy student development, (Johnson, Johnson, and Holubec 2008). It was also believed that, both cooperation and competition are essential in promoting students' interaction and enhancing the learning process, (Johnson, Johnson, and Smith 2006, 2014). However, several studies claimed that the cooperative approach is the most important method in promoting positive interdependence among students, (Johnson, Johnson, and Holubec 2008). Other researchers went farther and claimed that, competition have negative effects on learners and their interactions (Muñoz-Merino et al. 2014).

Cooperative learning is the process in which small groups of learners cooperate to achieve a shared task. Cooperation has two forms; the first is the formal one in which the teacher has to define the learning objective, the size and the members of the group, the tasks and the role of each group member, and the group-meeting plan. The teacher has also to explain the criteria for success, and monitor and assess students' learning to provide task assistance and improve the group working skills (Johnson, Johnson, and Holubec 2008).

In the second, the informal form, the teacher has to form the groups and set a shared goal, raise students' attention to the material to be learned, set the learning expectations, ensure students cognitive engagement, and provide a closure instructional session on the learning process (Johnson, Johnson, and Holubec 2008). In their studies on university teaching, Johnson et al., asserted that cooperative learning underlies several types of active learning methods. Among these are problem-based learning, case-based learning, project-based learning, and inquiry. They believed that, the cooperation activities have to foster the students' positive interdependence, individual accountability, and social skills (Johnson, Johnson, and Smith 2006, 2014).

Recently, several studies proposed cooperative-learning approaches and studied their impact on electric engineering students. Among these are the impact of learning methods on students' preferences, attitudes, perception of learning, and soft skills (Magana, Vieira, and Boutin 2018; Korkmaz 2018; Yadav et al. 2011; Verbic, Keerthisinghe, and Chapman 2017). However, according to our knowledge, none of the studies found in the literature considered the impact of intergroup competition, with inquiry and simulation, on learning electrical engineering.

Despite the claimed disadvantages of competition, several studies showed that competition could improve learning. Researches that support competitive learning, believe that, competition increases the challenge and excitement and promotes intrinsic motivation (Tauer and Harackiewicz 1999; Reeve and Deci 1996). They also believe that, the learners who enjoy what they are doing become more involved in the learning activity and spend more time in improving their performance (Harackiewicz and Sansone 1991). Other researchers believe that, positive feedback in competitions fosters the intrinsic motivation and enhances the learning performance (Tauer and Harackiewicz 1999; Reeve and Deci 1996). Researchers also believe that, cooperation and competition are parallel motivations and behaviors, therefore they can coexist simultaneously (Fülöp 2002, 2004).

To improve the outcome of a competition, researchers introduced the concept of appropriate and constructive competition. Appropriate competition is defined as the competition in which there is not a heavy emphasis on winning, opponents are equally matched; rules are clear and straightforward, and participants are able to measure their progress relative to their opponent. Stanne et al., found that there is no difference between cooperation and appropriate competition on motor activities performance (Stanne, Johnson, and Johnson 1999). Constructive competition is defined as a social and cultural phenomenon that enhances learners' abilities, develops their ambitions, and fosters learning (Fülöp 2002, 2004). Sheridan and Williams defined a constructive competition as a multidimensional educational phenomenon that motivates learners to stretch their abilities beyond their expectations (Williams and Sheridan 2010; Sheridan and Williams 2011). They believed that, constructive competition does not prohibit individuals' learning in the same particular area. It also creates the conditions to challenge the teachers and learners abilities and experiences. Moreover, it gives the teachers the opportunities to form and influence the learning environment so that they can facilitate competition, cooperation, and individual work. Sheridan and Williams expected a constructive competition to have neither winners nor losers, compare competences, construct motivation, include reciprocal guidance, employ the will to win, and stretch learner potentials beyond their expectations.

Competition and cooperation are not only present at an individual level. They also occur at the group level at most of the activities. In fact, the members of a group can compete with other groups and compete among each other for the role of the group 'best member'. Despite this, they can cooperate to achieve shared goals that they compete with others. Intergroup competition integrates the characteristics of both cooperation and competition and can have positive effects on learning and learners. A constructive intergroup competition is a group competition that enhances outcomes and productivity. In constructive intergroup competition, groups are all winners but have different prizes. Moreover, the will to win is employed to foster the groups' motivation and group members' cooperation and abilities. In addition, a constructive intergroup competition provides the groups with the ability to compare their competences and achieve a reciprocal guidance. Mulvey and Ribbens found some evidence that, intergroup competition is constructive and improve the group productivity and academic performance (Mulvey and Ribbens 1999; Okebukola 1986). Tauer et al. found a strong and consistent evidence that, intergroup competition leads to more positive outcomes than pure cooperation and pure competition, (Tauer and Harackiewicz 2004). Their final recommendation was that, researchers should examine the joint positive effects of cooperation and competition rather than treating them as polar opposites. Recent studies on intergroup competition showed that, the students achieved high engagement, creativity, and learning outcomes (Cheng-Huan and Chiung-Hui 2016).

Role of inquiry and computer-simulation in learning

Literature review showed that, active engagement in learning plays a fundamental role in students' achievement. Researchers posited that, the investigation of authentic and relatively complex problems motivates learners and engages them in acquiring and integrating new knowledge (Knight and Wood 2005). Inquiry and computer simulation were frequently used to investigate authentic problems (Houlden et al. 2004; Abell 2005; Parush, Hamm, and Shtub 2002; Hugerat and Kortam 2014).

Inquiry-based learning is one of the learner-centered models that can foster autonomous learning and activate several aspects of engagement. In fact, inquiry is a self-directed learning method in which the students take more responsibility for determining what they need to learn, identifying resources and determining how to use them, reporting their learning, and assessing their progress (Lee 2004). It is generally believed that, the inquiry-based learning is more effective than traditional teaching for achieving a variety of students learning outcomes. Among these are academic achievement, student perceptions, process skills, analytic abilities, critical and higher-level thinking, and creativity (Hugerat and Kortam 2014; Houlden et al. 2004). Several studies were developed to assess the effects of inquiry-based learning in a wide range of disciplines (Houlden et al. 2004; Abell 2005; Spronken-Smith et al. 2008; Luke 2006). However, researchers found that, the implementation of an inquiry is more difficult than traditional teaching (Wallace and Louden 2002). It also needs more time and requires ad-hoc follow-up and assessment methods to ensure the construction of a structured knowledge by the students (Riga et al. 2017). To overcome these problems and to make the inquiry more interesting and engaging, several studies supported their inquiries with computer applications such as games and simulation (Jacobson, Taylor, and Richards 2016). Our approach integrates inquiry and computer simulation.

A computer-simulation is defined as a program that can be repeatedly changed and re-run in order to understand the behavior of an interactive model (Alessi 2000). Parush et al., identified that the presence of a learning history, which allows students to stop, rewind or restart the model simulation at any point, resulted in better understanding and also better long-term retention of knowledge (Parush, Hamm, and Shtub 2002). Obviously, both modeling knowledge and simulation skills are necessary for the success of a simulation-based learning. Strijbos et al., investigated the importance of using simulation in learning to promote other important skills, such as argumentation and negotiation (Strijbos, Martens, and Jochems 2004). These skills are promoted, by simulation, in open-ended tasks such as those defined by inquiry and competition. Several studies showed that the use of simulation with a well-structured inquiry is more effective for promoting science content knowledge and other process skills than the traditional approach (Rutten, Van Joolingen, and Van der Veen 2012). Löhner et al., found that students have difficulty in using language based modeling simulators, and thus, advised to use graphical modeling simulators (Löhner, Van Joolingen, and Savelsbergh 2003).

Method

Sample

Sixty-four students, age 19–20, of the Electric-Circuits II course were voluntarily involved in the study. The students were second-year students who passed the mathematical requirements courses and Electric-Circuits I. Although the students worked in groups in the two physics laboratory courses, they were never exposed to active learning methods and simulation tools. The new-approach design was illustrated to all the sixty-four students in the phase of forming the groups. A final reward, in terms of bonus marks, was introduced to raise the students' external motivation to participate and learn through the new-approach. Accordingly, thirty-two students decided voluntarily to participate in the new-learning activities (study-group) and the others decided to follow the traditional-lecturing (control group).

To construct a more comfortable learning environment, that overcomes gender-related socio-cultural issues and students' availability out of class-time, the authors relaxed the group formation conditions. The students were given the freedom to select their partners and form groups of four members. There were two female-groups, three male-groups, and three mixed ones. The study-group students followed a class session in which the new-approach detailed structure, rules, and tools were illustrated.

Procedure

The new-approach was designed to emulate the general framework of sports competition. It included a preparation-phase and a final confrontation. The preparation-phase included most of the learning activities, whereas, the final confrontation was a face-to-face question/answer debate on electric filters. Four teaching assistants; one for two groups, helped in monitoring the learning activities and observed and reported the students attitudes during these activities. The teaching assistants were instructed to follow up students' activities, take notes, and avoid interfering in the learning tasks. In case of a student-stuck in simulation tools, the teaching assistants were allowed to give hints, such as the titles of toolbox or the resources in which the student can find related information. The instructor provided feedback information and hints without interfering in the learning activities.

The preparation-phase was based on a simple inquiry on analog electric-filters. To apply jigsaw, various filter types and model generators were used. Filter types were Low-Pass (LP), High-Pass (HP), Band-Pass (BP), and Band-Reject (BR). Whereas, model-generators were Direct-Form, Butterworth, Chebyshev, and Bessel. The set of selected filters covered more electric-filter topics than what is taught in the traditional method. In fact, the Chebyshev and Bessel filters were not part of the traditional-course outline. The additional filter-generators were used to motivate the students to learn from different information resources and foster student learning autonomy. Each group was assigned four different filter-circuits of different types and generators. Each group-member had to develop his own inquiry based on one filter-circuit of a specific type and generator, for example, the four members of a group were assigned Butterworth LP, Chebyshev BP, Bessel BR, and direct-form HP, respectively. The group-members had then to share and exchange their knowledge in a jigsaw style in their group meetings. At the start of the preparation-phase, two simulation packages were introduced in a two-hour introductory session; a graphical-level simulator, ORCAD, and a mathematical model-based one, MATLAB.

The inquiry was developed through three working steps with an increasing employment of simulation skills, Figure 1. A supervised group meeting to construct the group knowledge followed each step. In the first week, each student learned ORCAD interfaces, functions, and output presentation methods. Each student was asked to use the acquired simulation skills to simulate his filter-circuit and determine the frequency response characteristic parameters and its relation to their filter type.

In the second week, each student repeatedly changed his circuit parameters and analyzed their effects on the filter frequency response. The student was also asked to

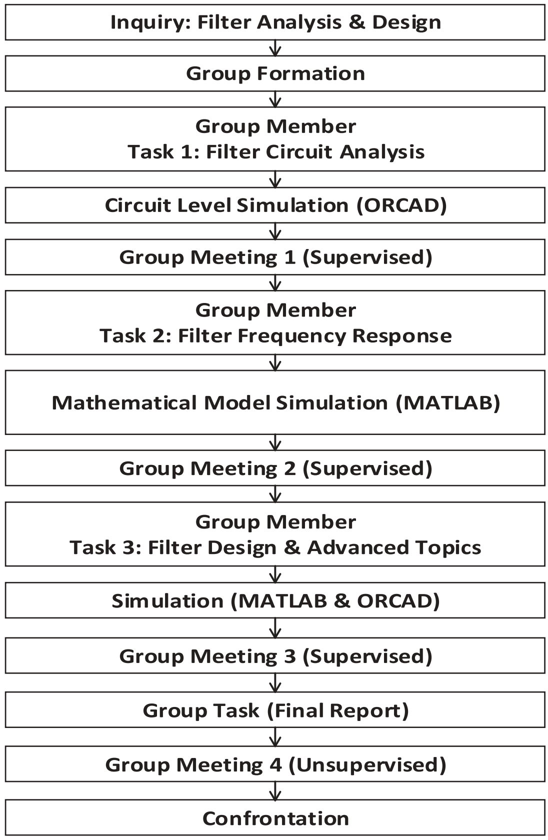


Figure 1. Preparation phase task flow and cooperation plan.

describe the amplitude, phase, and the significant-frequency extension of the filter. At the end of this step, the students held a meeting in which they presented, shared, and discussed their results. The instructors monitored the meeting, and assessed the progress, autonomy and accountability, and engagement of each group member. The students exchanged their simulations and results for further discussions after the meeting.

In the third-week, each student learned MATLAB and used scripts to simulate his filters' model-generator. He derived the relations between the filter model and the circuit parameters. The student also used a trial-and-error procedure to estimate the parameters that achieve a set of desired filter specifications. At the end of this phase, each student looked for information about his filter in different information resources, including books, scientific papers, and Internet websites. Then, the group members of each group, prepared a group presentation in which they integrated their work.

To achieve the appropriate-competition conditions and implement an intra-group learning step, the students of the entire study-group held a shared supervised meeting and used a presentation software to illustrate their work. Each student presented a part of his group presentation and at end, the instructors provided the students with feedback and comments.

In the last step of the preparation phase, each student looked for practical applications of his filter. Then, the group members studied, analyzed, and compared the application filters with their own filters. The students also discovered the existence of other filter topics that were not covered by their inquiry. For example, digital filters, Gaussian filters, and filter banks. At the end of this step, the group members held a supervised meeting in which they talked about and discussed filter applications. At this meeting, the intervention of the instructors was limited to giving instructions about the format of the final group-report. To add another learning iteration, the instructors asked the students to prepare a knowledge-guided report and avoid student-oriented sections. That is, the students were asked to hold a final meeting and write their reports by mixing and integrating their results in each paragraph.

The confrontation phase included three different learning activities, Figure 2. In the first, a test sheet was administered to the students as individuals. The students had to answer the sheet in thirty minutes. A penalty condition was assigned to unanswered questions, i.e. any erroneous answer causes the loss of one point, and any unresolved question causes the loss of two points. This rule aimed to reinforce the critical-thinking process by forcing the student to think about a plausible answer. In the second activity, pairs of opponent members had to answer all the questions on the sheet in fifteen minutes. Any erroneous answer causes the loss of one point to the pair-groups. The pair could also decide to remove a set of questions from being part of the question-answer competition. In this case, their groups lose two points. This aimed at encouraging the opponent students to cooperate through their responsibility toward their groups.

The last learning activity was the question/answer competition on electric-filters theory and simulation skills. In this activity, group-pairs were randomly selected to compete with each other. According to the competition rules, each group member had to ask a question to an opponent with a one-to-one strategy and with no repeated selection of opponents. This approach aimed to reinforce the accountability of all the group members. The instructors evaluated the answers based on the points-based system.

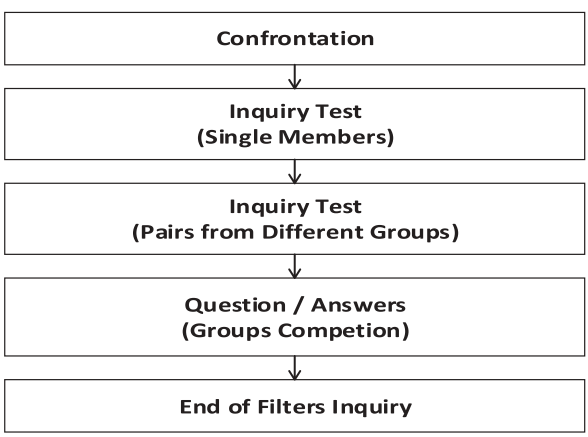


Figure 2. Competition phase activities.

The intergroup competition 'winner-group' and 'winner-learner' were those who achieved the maximum number of points. In the adopted points system, each student and each group start with the negative points collected at the first and second activities, respectively. Then, a correct answer from the target-group adds four points to the group if it comes from the selected-student; otherwise, only two points are added. When the target-group members fail, the student who asked the question is given the possibility to answer his question. If his answer is correct, two points are added to his group. In all cases, two points are added to the group when the right answer is supported by simulation. Two points are also added to the score of the student who gives the correct answer.

Data collection and analysis

The study employed a variety of data collection tools, including pretests and posttest, questionnaires, direct observation, and students' portfolios. Two tests on filter-knowledge and simulation, with scores out of 100, and a Likert questionnaire were used to answer the questions of the study. The students' achievement in learning electric-filters was also assessed by the traditional final exam. When the questionnaire was administered to the students, the authors explained the questionnaire items and informed the students that the comparison is between the new-approach and the traditional-lecturing. Although the control-group followed the traditional-lecturing approach, the questionnaire was administered and answered by all the sixty-four students of both the study and control groups. The administration of the questionnaire to the study-group students aimed to inspect if following the new-approach could change the study-group perceptions of the role of engagement and cooperation in learning. Knowing that the students of both groups interact with each other's, through their presence in the same space and their mixing in other courses, the authors wanted to inspect if the new-approach could also affect the perception of the roles of engagement and cooperation of other students, represented by the control group.

Paired T-test with significance level 0.05 and degrees of freedom 31, and independent T-tests with significance level 0.05 and degrees of freedom 62, were used to analyze the collected data. Data was analyzed using SPPS-20.

The Likert questionnaire was a five-level twenty items questionnaire. It had two scales that aimed to assess students' perception of the role of engagement and cooperation in learning, Table 1. The results of the negative-worded questions, 6, 8, 14, and 18, were reversed and the levels were numerically encoded as: strongly-Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, and Strongly-Agree = 5. The reliability of each Likert scale was insured using the Cronbach's alpha coefficient (α), Table 2. In fact, the reliability coefficients were between 0.76 and 0.84.

Direct observation and portfolios data, were used to make sure that the students were engaged and practiced autonomy in their learning. This data was collected during the groups' presence in the workroom, the supervised meetings, and portfolios. Points-system was used to assess the students' engagement and cooperation. Students' engagement was measured in terms of their involvement in the working activities, their persistence in solving problems, the employed-time in and out of the workroom, and the expressed enjoyment-level (in a scale from one to ten). Cooperation was

Table 1. Likert-scale questionnaire on the students' perception of the role of cooperation and engagement in learning.

Answer the questions with: Strongly-Agree, Agree, Neutral, Disagree, or Strongly-Disagree
Cooperation-Scale items
1. I think that the new-approach in learning electric filters specifies precisely the targeted outcome of the learning process.
2. I think that the new-approach in learning electric filters enriches the learning skills of the group.
3. I think that the new-approach in learning electric filters enhances the ability of the group members in presenting their learning results.
4. I think that the new-approach in learning electric filters enhances intergroup sharing of information
5. I think that the new-approach in learning electric filters makes group-members more unite.
6. I think that the new-approach in learning electric filters decreases the need for a group working-plan.
7. I think that the new-approach in learning electric filters enhances inter-group interaction
8. I think that the new-approach in learning electric filters de-emphasizes the accountability of each group-member.
9. I think that the new-approach in learning electric filters enriches the learning skills of each group member.
10. I think that I will voluntarily participate in a learning process that involves cooperation in learning with the new-approach.
Engagement-Scale items
11. I think that the new-approach in learning electric filters fosters the motivation to study electric filters.
12. I think that the new-approach in learning electric filters leads to higher excitement in learning electric filter concepts.
13. I think that the new-approach in learning electric filters leads to higher enjoyment in learning electric filter concepts.
14. I think that the new-approach in electric filters leads to lower commitment in learning electric filters.
15. I think that the new-approach in learning electric filters fosters the employment of higher efforts in understanding filters concepts.
16. I think that the new-approach in learning electric filters leads to the engagement of deeper thinking in filters concepts.
17. I think that the new-approach in learning electric filters encourages higher involvement in learning activities.
18. I think that the new-approach in learning electric filters weakens the belief in the potential of self-teaching.
19. I think that the new-approach in learning electric filters fosters the employment of higher efforts in encouraging other group members.
20. I think that I will invest voluntarily more time and efforts in a learning process that involves the new-approach activities.

Table 2. The reliability Cronbach's α-coefficients of the Likert questionnaire before and after the teaching process.

Likert Questionnaire α-coefficients	Study-Group (new-approach)		Control-Group (traditional-lecturing)	
	Before	After	Before	After
Cooperation-Scale	0.79	0.83	0.76	0.78
Engagement-Scale	0.81	0.82	0.84	0.81

assessed in terms of participation in discussion, personal interventions, group cohesiveness, and the assistance provided to the other group members. However, the engagement and cooperation levels were not part of the study variables. The qualitative measurements were only used to make sure the sufficient level of learners' engagement and cooperation in the learning activities.

Points-method was also used to assess the electric-filters question/answer debate and simulation skills. A test was used to implement an intra-group learning step and reduce the emphasis on winning. The results of this test were used to set the initial group-scores in the final electric-filters debate. A reward was used as an external motivator for competition winning and best performing. In the proposed rewarding system, all the students that participate in the final face-to-face confrontation win three bonus-marks.

The students of the winning groups win additional three marks and the winner-learner gets extra two marks.

Results

Students ability to learn autonomously

To answer the first question of the study, about the students' ability to learn autonomously, paired T-tests were used to analyze the study-group results. Results, Table 3, showed that the mean-values of the study-group results in filter knowledge, and simulation changed from (9.77, 6.19) before the new-approach to (79.03, 77.44) after its application. Both paired T-tests on filter-knowledge and simulation rejected the null-hypothesis of equality of students' achievements' before and after the application of the new-approach (p-values = 0.000). Thus, they confirmed that the students succeeded in learning autonomously through the activities of the new-approach. Their achievements were even better than the achievements of the control-group that followed the lecturing-approach.

Impact of the intergroup competition on students' achievements in learning

To answer the second question of the study, paired T-tests were used to analyze the results of the study and control groups. These tests were applied to test the students' achievements in filter-knowledge and simulation before and after the application of the teaching actions, that is learning through the new-approach for the study-group and through traditional lecturing for the control-group. Results, Table 3, showed that before the teaching action, the achievements of both groups were very low with mean-values in filter-knowledge (9.75, 10.31) and simulation (6.19, 7.0). The independent T-tests could not reject the null-hypothesis of equality of students' achievements for both filter-knowledge and simulation (p-values 0.7 and 0.34). Thus, the T-tests confirmed that there were no initial statistical differences between the study and control groups.

After the application of the end of the teaching actions, both the study and control groups showed a significant improvement in filter-knowledge; however, the study-group improvement was higher than that of the control-group (79.03, 54.88). Independent T-test showed that the null-hypothesis, about the equality of achievements of the two groups after the application of the teaching actions, was rejected with (p-value = 0.000). Thus, it confirmed that there was a significant statistical difference between the achievements of the two groups in favor of the study-group.

Table 3. Mean and standard deviation (SD) of tests before and after the teaching actions.

Test	Study-Group (new-approach)				Control-Group (traditional-lecturing)			
	Before		After		Before		After	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Filter-knowledge	9.75	5.91	79.03	9.42	10.31	5.54	54.88	8.90
Simulation	6.19	3.06	77.44	9.78	7.00	3.64	8.16	4.78
Traditional			84.84	10.42			76.39	10.77

Moreover, the results of the traditional final-exam questions on electric-filters showed that both groups achieved relatively high mean scores, Table 3. The achievement of the study-group was also higher than that of the control groups (84.84, 76.39). In this case, the independent T-test also confirmed the existence of a significant statistical difference between the achievement of the two groups in favor of the study-group (p-value = 0.002).

The T-test on simulation showed similar results and confirmed the existence of a significant statistical difference between the two groups. However, the control-group showed an insignificant improvement (8.16) with respect to the achievement of the study-group (77.44).

In conclusion, despite the extension of the desired learning outcomes of the electric-filters part of the course, the study-group students achieved better than the control-group.

Perception of the role of cooperation in learning

To answer the question about the impact of the new-approach on the students' perception of the role of cooperation in learning, a paired T-test was used. The distributions of the students' answers to the cooperation-scale items, before and after the application of the new-approach, are shown in Figure 3. The figure shows a net shift, toward agree and strongly-agree, in all the cooperation scale items. Results, Table 4, also showed a shift in the mean-value of the cooperation-scale from (2.85) before to (3.92). Thus, reviewing the used coding of the questionnaire, one can observe a positive shift in the study-group students' perception of the role of cooperation in learning.

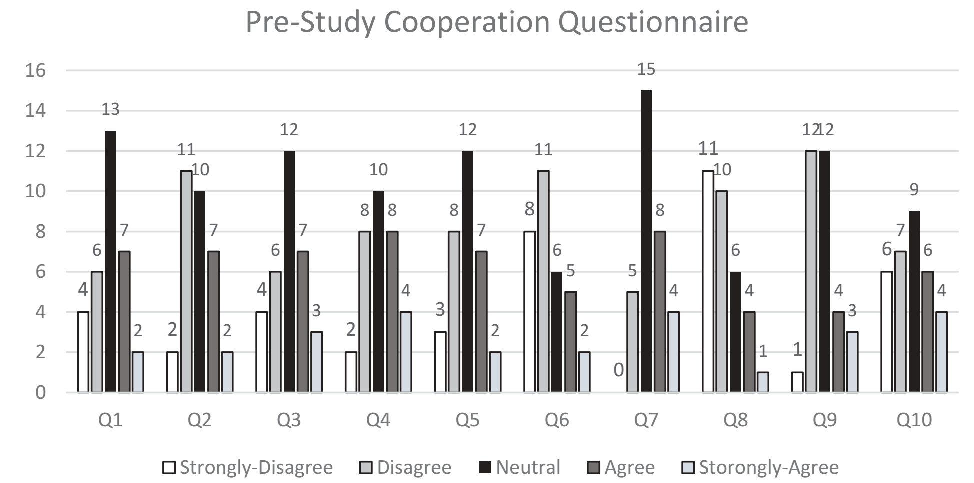
The T-test showed that this shift is statistically significant (p-value = 0.000). Therefore, the null hypothesis of equality of the students' perception of the role of cooperation in learning, before and after the application of the new-approach, is rejected.

To compare these results with those of the control group, paired T-tests were used to analyze the answers of the control-group before and after the traditional-lecturing process. Whereas, independent T-test was used to determine if there was a significant statistical difference, in the perception of the role of cooperation, between the students of the study and control groups. Results of the control-group, Table 4, showed that the mean-values of the cooperation-scale were (2.84) before and (2.85) after the lectures. The paired T-test could not reject the null hypothesis of equality of the control-group perception of the role of cooperation before and after lecturing (p-value = 0.630). Moreover, the results of the independent T-tests before the study could not reject the hypothesis of equality of the two groups (p-value = 0.995). Whereas, the same tests confirmed the existence of a significant difference, in favor of the study-group, after the application of the new-approach (p-values = 0.000).

In conclusion, results confirmed that the new-approach had a positive impact on the study-group students' perception of the role of cooperation in learning, but it could not affect the perceptions of the control-group.

Perception of engagement in learning

The same procedure, used for the Cooperation-Scale, was applied to the Engagement-Scale. The distributions of the students' answers to the engagement-scale items, before



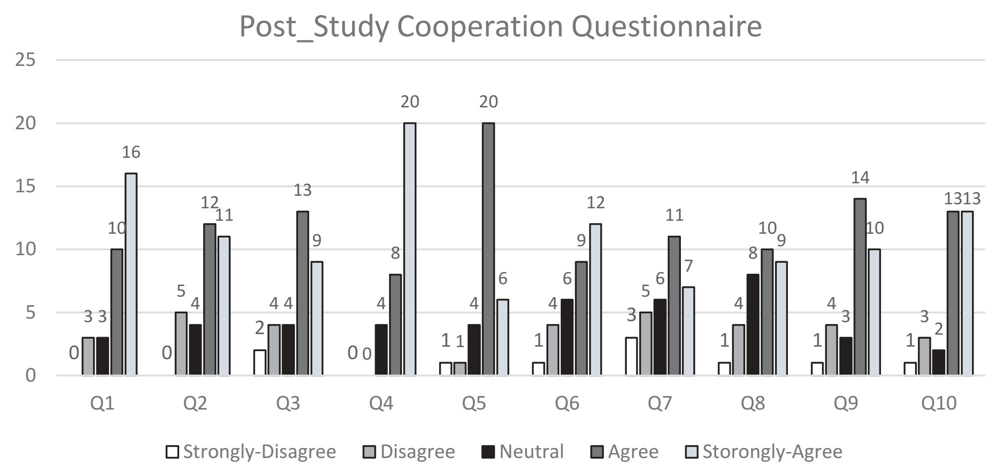


Figure 3. Pre-study and post-study results of the questionnaire that assesses the *students'* attitude toward cooperation in Table 1.

Table 4. Mean and standard deviation (SD) of the Likert-scales before and after the teaching actions.

Questionnaire	Study-Group (new-approach)				Control-Group (traditional-lecturing)			
	Before		After		Before		After	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cooperation-Scale	2.85	0.65	3.92	0.66	2.84	0.67	2.85	0.65
Engagement-Scale	2.85	0.67	4.08	0.59	2.77	0.75	2.82	0.73

and after the application of the new-approach, are shown in Figure 4. These results show a net positive shift in all the scale-items toward agree and strongly-agree. Table 4 also shows that there is a net positive shift in the mean-values of the students' answers to the Engagement-Scale from (2.85) before to (4.08) after the application of the new-approach.

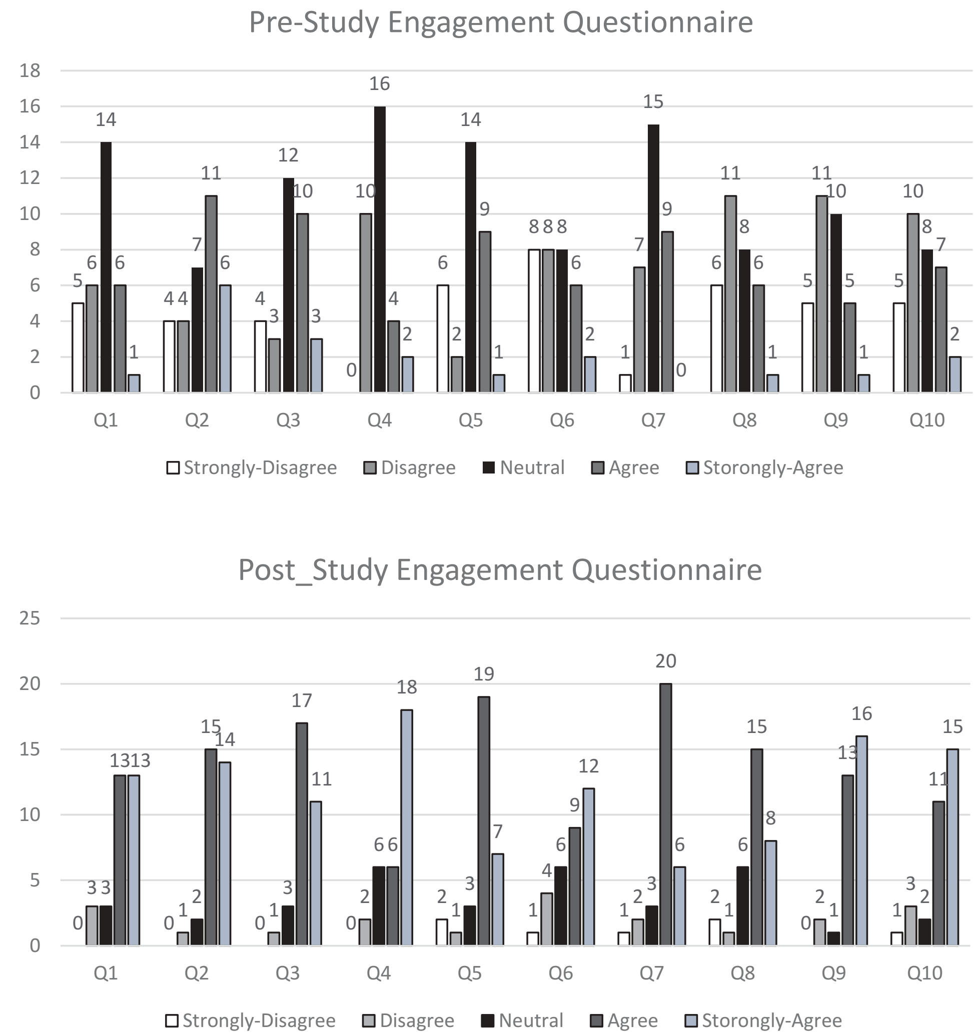


Figure 4. Pre-study and post-study results of the questionnaire that assesses the students' attitude toward engagement in Table 1.

The paired T-test confirmed that this shift was statistically significant (p-value = 0.000). Thus, the null-hypothesis on the equality of the students' perception of engagement in learning, before and after the application of the new–approach, is rejected.

The control-groups mean-values in the engagement-scale items were (2.77) before and (2.82) after the lectures, Table 4. The paired T-test could not reject the null-hypothesis of equality in the perception of engagement, of the control-group, before and after lecturing (p-value = 0.219). Moreover, the results of the independent T-tests before the teaching actions could not reject the hypothesis of equality of the two groups in the perception of engagement (p-value = 0.661). Whereas, the same test showed a significant statistical difference, in favor of the study-group, after the application of the new-approach (p-value = 0.000).

Thus, the data analysis confirmed that the new-approach had positive impacts on the study-group students' perception of engagement but did not affect the control-group.

Discussion

The authors aimed to develop a learner-centered approach to expose the second-year electrical engineering students to their first experience in non-traditional lecturing. They posed four questions about the students' achievement and outcomes in learning filter theory and simulation, the students' ability to learn autonomously, the students' perceptions of the role of engagement and the role of cooperation in learning. To answer these questions, the authors designed a learning procedure that includes inquiry, computer simulation, and cooperation in an intergroup competition framework. Instead of evaluating the effects of each method individually, the authors' objective was to study the integral effects of the new-approach on the study variables. Therefore, results are discussed as the new-approach outcomes. They will not generally refer to the effects of any method individually.

The authors believe that, the new-approach was effective and fruitful. This was shown by the results of the tests, the questionnaires, direct observation, and students' portfolios. In fact, the analysis of all tests results in filter theory showed that the students of the study-group achieved better than those that followed the traditional-lecturing approach. They also succeeded in learning additional filter topics and filter simulation. Simulation tests showed also that the study-group students achieved better results than those of the lecturing-group; this can be justified by the fact that the traditional approach did not consider simulation as a requirement. Moreover, analysis of the traditional exam results showed that the study-group students' achievement was better than the students of the traditional-lecturing. However, the same analysis revealed that the students of the traditional-lecturing achieved good results. This can be justified by the fact that the traditional exam is generally designed to match the expected knowledge level transferred by the traditional-lecturing approach. The analysis of the questionnaire results showed that the proposed-approach could change the study-group students' perception of the role of engagement and cooperation in learning electrical engineering subjects. However, the direct interaction between the study-group and the control-group students could not affect the perceptions of the control-group students, which mean that the change of the students' perceptions of the role of cooperation and engagement in teaching requires that the students apply the new-approach activities.

Despite the benefits of the new-approach, the authors believe that the transformation of the students to autonomous active-learners was not an easy task. It included several challenges that both instructors and students had to overcome. In fact, the direct observation of the students' activities and inspection of the students' portfolios revealed that, in the first week, most of the students were skeptic and intimidated from the new experience. They were uncertain about how should they proceed, where should they look for the required information, and what information source to follow. The students looked for support from the instructors and not from their group members as expected by the cooperative learning conditions. They asked to be assisted by providing them with a list of information resources and websites in which they could find the required information and similar tasks. First-week observations also showed that, the students did not possess the necessary skills to direct their learning. Most of them felt and recognized that they were strictly dependent on their teachers. Observations also showed that, most of students were impatient and could not engage in learning. They could not also contribute with their own ideas or did not know if their ideas were in the correct direction to satisfy the inquiry requirements. The instructors understood this as the initial shock of autonomy and learner-centered activities; in fact, this was the students' first experience in non-traditional lecturing approach. The authors encouraged the students and asked them to have patience; they told them, during the meeting, that it was natural to have some problems because of the new experience. The instructors told the students about the small successes achieved by some of their colleagues. The instructors gave the students hints on how to proceed; that is, they asked them to use the simulation package help-option and to start with simple examples. As a result, all the groups persisted and felt challenged; they understood that the assigned tasks were not impossible to do.

During the second week, most of the student found their way toward their small achievements. The teaching assistants, of all the groups, reported that the students were very engaged in their tasks; they cooperated in learning simulation and enjoyed having successful results. They were proud of their finished tasks, and challenged their group-members and students of other group-members in simulation functions. During this week, the students also completed their assigned tasks. Moreover, during the supervised meeting, all the students showed good engagement levels and contributed in knowledge construction and integration. Students looked for the instructors' assistance less frequently. Thus, the authors found that encouragement, feedback hints, and success stories succeeded in guiding the students towards autonomy, engagement, and cooperation (Francom 2010). At this point, the instructors realized that their study is progressing toward the desired objectives. One can argue that the feedback given to the students compromised the students' autonomy. Again, it should be remembered that this was the students' first experience in active learning procedures. Moreover, the feedback was controlled and limited to hints and interrogatory questions. In addition, research on autonomy asserted that developing autonomy is not a natural process, but a gradual process in which the students must be instructed to interact positively with the learning environment (Francom 2010; Tauer and Harackiewicz 1999; Reeve and Deci 1996)

It is important to mention that, during the second week, the teaching assistants reported that some of the students were dependent on their colleagues in learning and developing their tasks, and did not follow the proposed jigsaw recommendations precisely. At this point, the instructors did not take any action to prohibit this behavior. They decided to sacrifice some of the individual autonomy and accountability for more positive interaction between the students. Nevertheless, to foster the responsibility toward autonomy, the instructors asked the teaching assistant to inform the students that their tasks and skills will be assessed individually during the supervised meeting.

It worth also mentioning that the inhomogeneity of the groups structure, caused by the fact that the student themselves formed their groups, affected the groups behavior. The instructors, in the supervised meeting, noticed three different group-behaviors. There were groups in which all the students were very active, enthusiastic, and had deep discussions. In other groups, all the students engaged appropriately and shared their information, but they did not showed to be involved in hot discussions. Whilst, in the third type, the instructors noticed the existence of dominant students that led the discussions and construction of knowledge. However, this inhomogeneity did not prohibit the groups from accomplishing their tasks. Moreover, none of the groups or group-members raised this issue as a problem or asked to withdraw from the study-group. During the third and fourth weeks, the teaching assistants reported that most of the students developed their tasks autonomously. Only three students looked for assistance from their colleagues. However, all the students showed high accountability in presenting their work during the third-week supervised meeting presentations. The follow-up of the students work during the last three weeks of the study showed that the students' ability to work autonomously improved gradually and continuously. By the end of the study period, all the students succeeded in fulfilling the required tasks with minimum intervention from the instructors. The tests results in filter theory and simulations showed that the students could direct their learning actions toward knowledge construction without any significant intervention from the instructors. All the mentioned facts show that, the students succeeded in their first autonomous learning experience.

Moreover, during the third and fourth weeks, all the students of the study-group showed progressive engagement, cooperation, and notable enjoinment. Observation and portfolios showed that the group members looked for each other and most of the time worked together, they looked for information in different resources and websites, shared information, analyzed and discussed filter applications and simulation results, and challenged each other. All these observations, besides to the results of the questionnaire analysis, show that the proposed approach fostered the study-group students' perception of the role of engagement and cooperation in learning.

Despite the achievement of good engagement and cooperation levels, some students of the study-group reported that they were exhausted by the difficulties they faced and the long-time they spent in learning through the new approach activities. However, none of the study-group members asked to withdraw from the study. When they were asked about this, the students asserted that they wanted to win the final reward bonus marks; therefore, they encouraged and supported each other to persist in the learning process (Tjosvold et al. 2006). They also said that they did not want to disappoint their friends and prohibit them from winning. This shows that the use of the final reward raised the group cohesiveness and enhanced the group members' cooperation and positive interaction.

On the other hand, observations of the traditional groups' activities and their portfolios showed that they did not show a similar behavior. However, it worth mentioning that the students of this group did not include much significant information in their portfolios. Although some of them reported that, they tried to exchange information with their study-group friends. This fact shows that, the student of the control-group were reluctant to invest time and effort to monitor their learning process. This make the authors believe that despite the involvement of the control-group students in the study and their interaction with the study-group students, the traditional-lecturing approach could not overcome the students' shallow involvement and individualistic perception of learning.

During the face-to-face confrontation, the students were very confident, enthusiastic; they enjoyed the debating process and learned from each other. They asked, answered, and practiced simulation to validate their answers. Direct observation and follow-up of the new approach-activities with the intergroup competition framework showed that the intergroup competition achieved the appropriate and constructive competition conditions. In fact, the students found the competition rules clear and applied them smoothly. All the groups felt challenged by their opponents and did their best to acquire the required knowledge and skills to win. The groups and their members shared information and assessed their knowledge level and progress during the preparation phase meetings and presentations; they could also assess their knowledge by the shared final confrontation test and the scores they got in the final face-to-face confrontation. The students did their best to win the competition; however, since the new-approach competition rules reward all the participants with bonus marks, there was not heavy emphasis on winning and the students considered the competition as a game in which all of them were winners. Moreover, there were no intergroup negative reactions.

Surprisingly, despite the positive interdependence among the group members shown in the preparation phase, some students showed negative feeling toward their group partners at the end of the final confrontation. In fact, these students blamed their partners for losing the competition. However, this negative reaction was limited to one group. The 'winner group' and 'winner student' were very proud of their achievement. They received congratulations from their instructors and colleagues.

In their reflections, both students and instructors expressed a common approval on the fact that the new-approach improved the social relations among the students and with their instructors. They also agreed that, learning electrical engineering is a two-sided process, in which the students must play an active role. The instructors expressed their satisfaction from the results; they also asserted that their perception of students' abilities was positively changed. The students also felt more confident about their abilities and expressed their satisfaction from the new experience. However, both the students and the instructors agreed that the new procedure is more time-consuming than the traditional lecturing. They also agreed that it needs the employment of more resources.

The students' reflections also showed that they would like to participate in future active learning activities, but they hoped that it would be applied in a widest context. That is, the activities should be planned to serve several courses and be vertically organized to employ the acquired skills repeatedly. Some students who expressed reluctance to future application of such activities reported as a major reason the fact that, the intensive employment of their time and resources in the new learning activities was tiring and affected negatively their achievement in other courses.

Finally, the instructors and the study-group students agreed that the new experience was exciting and fruitful.

Conclusions

The paper proposed a new approach in teaching the electric-filters part of the Electric Circuits II course. The new-approach implemented several active learning methods such as inquiry, computer simulation, and cooperation within an intergroup competition framework. It provided a learning environment in which the students engaged, cooperated, and practiced autonomous learning. Results revealed that the proposed approach improved the electrical engineering students learning outcomes and achievements in filter knowledge and simulation. Students' attitudes during the learning activities and their success in fulfilling the inquiry requirements, with minimum intervention from others, besides to their achievements in the tests showed that, the new approach fostered the students' autonomy in learning. Moreover, results showed that a short-period exposure, of the electrical engineering students, to the-new approach could change the students' perception of the role of engagement and cooperation in learning. The results of the study lead to believe that, long-term and well-planned application of the new-approach can change the students' attitudes toward learning and knowledge-construction. It can also provide the electrical engineering students with essential attitudes and skills that serve their future as electrical engineering professionals.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Abell, S. K. 2005. "University Science Teachers as Researchers: Blurring the Scholarship Boundaries." *Research in Science Education* 35 (2–3): 281–298. doi:10.1007/s11165-004-5600-x.

Alessi, S. 2000. "Building versus Using Simulations. Integrated and Holistic Perspectives on Learning." In *Instruction and Technology*, edited by J. M. Spector and T. M. Anderson. Dordrecht: Springer. doi:10.1007/0-306-47584-7_10.

Baer, M., R. Leenders, G. R. Oldham, and A. K. Vadera. 2010. "Win or Lose the Battle for Creativity: The Power and Perils of Intergroup Competition." *The Academy of Management* 53 (4): 827–845. doi:10.5465/amj.2010.52814611.

Betts, G. T., and J. Knapp. 1981. "The Autonomous Learner Model: A Secondary Model." In *Secondary Programs for the Gifted and Talented*. Los Angles, CA: National/State-Leadership Training Institute for the Gifted and Talented.

Cheng-Huan, C., and C. Chiung-Hui. 2016. "Employing Intergroup Competition in Multi-Touch Design-Based Learning to Foster Student Engagement, Learning Achievement, and Creativity." *Computers & Education* 103: 99–113. doi:10.1016/j.compedu.2016.09.007.

Davis, M. H., and J. M. McPartland. 2012. "High School Reform and Student Engagement." In *Handbook of Research on Student Engagement*, edited by S. L. Christenson, A. L. Reschly, and C. Wylie, 515–539. New York: Springer.

Francom, G. M. 2010. "Teach Me How to Learn: Principles for Fostering Students' Self-Directed Learning Skills." *International Journal of Self-Directed Learning* 7 (1): 29–44.

Fredricks, J. A., and W. McColskey. 2012. "The Measurement of Student Engagement: A Comparative Analysis of Various Methods and Student Self-report Instruments." In *Handbook of Research on Student Engagement*, edited by S. Christenson, A. Reschly, and C. Wylie, 763–782. New York, NY: Springer.

Fülöp, M. 2002. "Competition in Educational Settings." *Paper presented at The Faculty of Education*, Slovenia: University of Ljubliana.
Fülöp, M. 2004. "Competition as a Culturally Constructed Concept." In *Travelling Facts. The Social Construction, Distribution and Accumulation of Knowledge*, edited by C. Baille, E. Dunn, and Y. Zheng, 124–148. Frankfurt/NY: Campus Verlag.
Guglielmino, L. M. 2013. "The Case for Promoting Self-Directed Learning in Formal Educational Institutions." *SA-eDUC Journal* 10: 2.
Harackiewicz, J. M., and C. Sansone. 1991. "Goals and Intrinsic Motivation: You Can Get There from Here." In *Advances in Motivation and Achievement*, edited by M. L. Maeher and P. R. Pintrich, 7, 21–49. Greenwich, CT: JAI Press.
Henrie, C. R., L. R. Halverson, and C. R. Graham. 2015. "*Measuring Student Engagement in Technology-Mediated Learning: A* Review." *Computers & Education* 90: 36–53. doi:10.1016/j.compedu.2015.09.005.
Holec, H. 1981. *Autonomy and Foreign Language Learning*. Oxford: Pergamon. (First published 1979, Strasbourg: Council of Europe).
Houlden, R. L., J. B. Raja, C. P. Collier, A. F. Clark, and J. M. Waugh. 2004. "Medical Students' Perceptions of an Undergraduate Research Elective." *Medical Teacher* 26 (7): 659–661. doi:10.1080/01421590310001653937.
Hugerat, M., and N. Kortam. 2014. "Improving Higher Order Thinking Skills Among Freshmen By Teaching Science Through Inquiry." *Eurasia Journal of Mathematics, Science Technology Education* 10 (5): 447–454. doi:10.12973/eurasia.2014.1107a.
Jacobson, M. J., C. E. Taylor, and D. Richards. 2016. "Computational Scientific Inquiry with Virtual Worlds and Agent-based Models: New Ways of Doing Science to Learn Science." *Interactive Learning Environments* 24 (8): 2080–2108. doi:10.1080/10494820.2015.1079723.
Johnson, D. W., and F. Johnson. 2013. *Joining Together: Group Theory and Group Skills*. 11th ed. Boston, MA: Allyn & Bacon.
Johnson, D. W., R. Johnson, and K. Smith. 2006. *Active Learning: Cooperation in the University Classroom*. 3rd ed. Edina, MN: Interaction.
Johnson, D. W., R. T. Johnson, and E. J. Holubec. 2008. *Cooperation in the Classroom*. 8th ed. Edina, MN: Interaction.
Johnson, D. W., R. T. Johnson, and K. A. Smith. 2014. "Cooperative Learning: Improving University Instruction by Basing Practice on Validated Theory." *Journal on Excellence in College Teaching* 25 (3&4): 85–118.
Kember, D. 1997. "A Reconceptualization Of The Research Into University Academics Conceptions Of Teaching." *Learning and Instruction* 7 (3): 255–275. doi:10.1016/S0959-4752(96)00028-X.
Knight, J., and W. B. Wood. 2005. "Teaching More by Lecturing Less." *Cell Biology Education* 4 (4): 298–310. doi:10.1187/05-06-0082.
Korkmaz, Ö. 2018. "The Effect of Project-based Cooperative Studio Studies on the Basic Electronics Skills of Students: Cooperative Learning and Their Attitudes." *International Journal of Modern Education and Computer Science* 5: 1–8.
Lee, V. S. 2004. *Teaching and Learning through Inquiry: A Guidebook for Institutions and Instructors*. Virginia: Stylus.
Löhner, S., W. R. Van Joolingen, and E. R. Savelsbergh. 2003. "The Effect of External Representation on Constructing Computer Models of Complex Phenomena." *Instructional Science* 31 (6): 395–418. doi:10.1023/A:1025746813683.
Luke, C. L. 2006. "Fostering Learner Autonomy in a Technology-Enhanced, Inquiry-Based Foreign Language Classroom." *Foreign Language Annals* 39 (1): 71–86. doi:10.1111/flan.2006.39.issue-1.
Magana, A. J., C. Vieira, and M. Boutin. 2018. "Characterizing Engineering Learners' Preferences for Active and Passive Learning Methods." *IEEE Transactions on Education* 61: 1. doi:10.1109/TE.2017.2740203.
Malan, S. B., M. Ndlovu, and P. Engelbrecht. 2014. "Introducing Problem-Based Learning (PBL) into a Foundation Program to Develop Self-Directed Learning Skills." *South African Journal of Education* 34 (10): 1–16. doi:10.15700/201412120928.

Mason, L., P. Boscolo, M. C. Tornatora, and L. Ronconi. 2013. “Besides Knowledge: A Cross-sectional Study on the Relations between Epistemic Beliefs, Achievement Goals, Self-beliefs, and Achievement in Science.” *Instructional Science* 41 (1): 49–79. doi:10.1007/s11251-012-9210-0.

Mulvey, P. W., and B. A. Ribbens. 1999. “The Effects of Intergroup Competition and Assigned Group Goals on Group Efficacy and Group Effectiveness.” *Small Group Research* 30 (6): 651–677. doi:10.1177/104649649903000601.

Muñoz-Merino, P. J., M. Fernández Molina, M. Muñoz-Organero, and C. Delgado Kloos. 2014. “Motivation and Emotions in Competition Systems for Education: An Empirical Study.” *IEEE Transactions on Education* 57 (3): 182–187. doi:10.1109/TE.2013.2297318.

Okebukola, P. A. 1986. “Impact of Extended Cooperative and Competitive Relationships on the Performance of Students in Science.” *Human Relations* 39 (7): 673–682. doi:10.1177/001872678603900706.

Parush, A., H. Hamm, and A. Shtub. 2002. “Learning Histories in Simulation-Based Teaching: The Effects on Self-Learning and Transfer.” *Computers & Education* 39: 319–332. doi:10.1016/S0360-1315(02)00043-X.

Reeve, J., and E. L. Deci. 1996. “Elements of the Competitive Situation that Affect Intrinsic Motivation.” *Personality and Social Psychology Bulletin* 22 (1): 24–33. doi:10.1177/0146167296221003.

Reeve, J., and C. M. Tseng. 2011. “Agency as A Fourth Aspect of Students’ Engagement during Learning Activities.” *Contemporary Educational Psychology* 36: 257–267. doi:10.1016/j.cedpsych.2011.05.002.

Renninger, K. A., and J. E. Bachrach. 2015. “Studying Triggers For Interest And Engagement Using Observational Methods.” *Educational Psychologist* 50 (1): 58–69. doi:10.1080/00461520.2014.999920.

Riga, F., M. Winterbottom, E. Harris, and L. Newby. 2017. “Inquiry-based Science Education.” In *Science Education: An International Course Companion*, edited by K. S. Taber and B. Akpan, 247–261. Rotterdam, the Netherlands: Sense Publishers.

Rutten, N., W. R. Van Joolingen, and J. T. Van der Veen. 2012. “The Learning Effects of Computer Simulations in Science Education.” *Computers & Education* 58 (1): 136–153. doi:10.1016/j.compedu.2011.07.017.

Sheridan, S., and P. Williams. 2011. “Developing Individual Goals, Shared Goals, and the Goals of Others: Dimensions of Constructive Competition in Learning Contexts.” *Scandinavian Journal of Educational Research* 55 (2): 145–164. doi:10.1080/00313831.2011.554694.

Spronken-Smith, R., J. Bullard, W. Ray, C. Roberts, and A. Keiffer. 2008. “Where Might Sand Dunes Be on Mars? Engaging Students through Inquiry-based Learning in Geography.” *Journal of Geography in Higher Education* 32 (1): 71–86. doi:10.1080/03098260701731520.

Stanne, M. B., D. W. Johnson, and R. T. Johnson. 1999. “Does Competition Enhance Or Inhibit Motor Performance: A Meta-Analysis.” *Psychological Bulletin* 125 (1): 133–154.

Strijbos, J. W., R. L. Martens, and W. M. G. Jochems. 2004. “Designing for Interaction: Six Steps to Designing Computer-Supported Group-Based Learning.” *Computers & Education* 42: 403–424. doi:10.1016/j.compedu.2003.10.004.

Tauer, J. M., and J. M. Harackiewicz. 1999. “Winning Isn’t Everything: Competition, Achievement Orientation, and Intrinsic Motivation.” *Journal of Experimental Social Psychology* 35 (3): 209–238. doi:10.1006/jesp.1999.1383.

Tauer, J. M., and J. M. Harackiewicz. 2004. “The Effects of Cooperation and Competition on Intrinsic Motivation and Performance.” *Journal of Personality and Social Psychology* 86 (6): 849–861. doi:10.1037/0022-3514.86.6.849.

Tjosvold, D., D. W. Johnson, R. T. Johnson, and H. F. Sun. 2006. “Competitive Motives and Strategies: Understanding Constructive Competition.” *Group Dynamics: Theory Research and Practice* 10 (2): 87–99. doi:10.1037/1089-2699.10.2.87.

Verbic, G., C. Keerthisinghe, and A. C. Chapman. 2017. “A Project-Based Cooperative Approach to Teaching Sustainable Energy Systems.” *IEEE Transactions on Education* 60: 3. doi:10.1109/TE.2016.2639444.

Wallace, J., and W. Louden. 2002. “Introduction to Laboratories.” In *Dilemmas of Science Teaching*, edited by J. Wallace and W. Louden, 36–37. New York, NY: RoutledgeFalmer.

Warburton, N., and S. Volet. 2012. "Enhancing Self-Directed Learning Through A Content Quiz Group Learning Assignment." *Active Learning in Higher Education* 14 (9): 9–22. doi:10.1177/1469787412467126.

Williams, P., and S. Sheridan. 2010. "Conditions for Collaborative Learning and Constructive Competition in School." *Educational Research* 52 (4): 335–350. doi:10.1080/00131881.2010.524748.

Wilson, D., D. Jones, F. Bocell, J. Crawford, M. J. Kim, N. Veilleux, T. Floyd-Smith, R. Bates, and M. Plett. 2015. "Belonging and Academic Engagement among Undergraduate STEM Students: A Multi-Institutional Study." *Research in Higher Education* 56 (7): 750–776. doi:10.1007/s11162-015-9367-x.

Yadav, A., D. Subedi, M. A. Lundeberg, and C. F. Bunting. 2011. "Problem-based Learning: Influence on Students' Learning in an Electrical Engineering Course." *Journal of Engineering Education* 100 (2): 253. doi:10.1002/j.2168-9830.2011.tb00013.x.

Yu, F. Y. 2001. "Competition within Computer-Assisted Cooperative Learning Environments: Cognitive, Affective, and Social Outcomes." *Journal of Educational Computing Research* 24 (2): 99–117. doi:10.2190/3U7R-DCD5-F6T1-QKRJ.