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# The Efficacy of GeoGebra Tool in Enhancing Electrical Machines and Drives Instruction*

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The two related articles (GeoGebra Tool: Development of Applications for Electrical Machines and Drives Teaching Support and The Efficacy of GeoGebra Tool in Enhancing Electrical Machines and Drives Instruction) are parts of the unique and comprehensive research approach to improving university instruction of electrical machines and drives. The second part of this educational investigation presents the evaluative research on the applicability and quality of the described set of applications. The students of electrical power engineering assessed the quality of the developed EMD GeoGebra applications as very important and useful tools for learning and mastering related courses. Finally, the usefulness and effectiveness of these applications are summarised in the conclusion of the paper.

**Keywords:** electrical machines, electrical drives; GeoGebra; distance learning; educational software evaluation

## 1. Introduction: Students' Evaluation of the EMD GeoGebra Applications

The evaluative research presented in this paper (Part II: Evaluation of Applications) follows the paper that presents the development of the GeoGebra software for EMD (electric machines and drives) teaching [1].

In the field of Electrical machines, there are many GeoGebra applications that can be find on the web. In the last few years, Laboratory for Electrical Machines, Drives and Automatics (EMDA laboratory, Faculty of Technical Sciences Čačak – FTS Čačak, Serbia) has been designing, developing and using new applications based on GeoGebra in several engineering courses mainly related to the electrical machines and drives. Software evaluation is an important phase of the software development process.

This paper provides evaluation of the more than 30 developed EMD GeoGebra application, as a set of teaching support in the field of electrical machines and drives [1].

List of the evaluated EMD GeoGebra applications described in [1]:

EF_C1: Instantaneous and effective values of voltage $u$(t), current $i$(t), current phase angle $\varphi$(t), active $P$, reactive $Q$ and apparent power $S$;
TR_C2: Determination of voltage drop by using Kapp diagram;
SM_C3: Torque of the synchronous reluctant machine;
DCM_C4-C10: Characteristics of the DC generators;
DCM_C11: Torque-speed characteristic of DC motor with separate / shunt excitation and 4 different added armature resistances;
DCM_C12: Torque-speed characteristic of the DC motor with series excitation and 4 different added armature resistances;
IM_C13: Torque-speed characteristic of the induction machine;
IM_C14: Circle diagram of the induction machine;
SM_27: Synchronization of the synchronous machine;
SM_28-31: Vector diagrams of the synchronous machine;
SM_C19-C20: Synchronous generator – PQ diagram of the TG and HG;
SM_C22-C24: Synchronous generator voltage drop determination;
SM_C25: V curves of the synchronous machine;
SM_C26: Three phase short circuit failure of the synchronous generator;
SPECEM_C27: Torque – speed characteristic of single-phase induction machine;
SPECEM_C28: Torque-speed characteristic of the universal motor.

Researchers have shown the positive effects of GeoGebra on the efficiency and effectiveness of learning and teaching topics related to science, technology, engineering, and mathematics [2]. Although the main research was focused on the teachers' use of GeoGebra software [3], the most important evaluators of educational software are their users–students. They can evaluate the educational value of the software (application) and its contribution and formative impact on their learning. In this research, the students have gained an insight into the specificity of the GeoGebra and developed EMD GeoGebra applications, specifi-

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cally applicable to the phenomena in the theory and practice of electrical machines and drives.

## 2. Methodology of the Evaluation of EMD GeoGebra Educational Applications

The goals of the evaluative research on the applicability and quality of the presented software (applications) are the following:

- The specific goals are: situational evaluation of the teaching process and courses of EMD supported by the EMD GeoGebra applications at the FTS Čačak;
- The broader goal is to gain insight into the applicability and effects of the EMD GeoGebra applications to improve the teaching process and students' achievement.

The developed EMD GeoGebra applications described in detail in Part I were evaluated by the students enrolled in EMD courses. The variables of this evaluative research are the following:

- students' university year (from the third to the fifth year of undergraduate and graduate levels of education);
- the number of EMD courses completed by students;
- the number of the EMD GeoGebra applications used by students;
- students' information and knowledge about GeoGebra software;
- students' assessment of the EMD GeoGebra applications consists of the following components:
  - evaluation and assessment of the EMD GeoGebra applications' technical characteristics;
  - assessment of the EMD GeoGebra applications' realistic appearance, suitability, and importance for this educational field;
  - assessment of the EMD GGP applications harmonization with the courses' goals;
  - assessment of the interactivity of the EMD GeoGebra applications;
  - assessment of the motivational contribution of the EMD GeoGebra applications for students' learning;
  - assessment of the contribution of EMD GeoGebra applications to students' effectiveness and research behaviour improvement;
  - students' self-assessment of knowledge about GeoGebra concepts and applications.

The survey instrument for this evaluation consists of two parts:

1. A questionnaire which consisting of two sections:
   (a) the questions about students' educational data, and
   (b) the questions about students' experience with the EMD GeoGebra applications;
2. Two assessment scales:
   - The EMD GeoGebra Applications Assessment Scale (EMD-GGA-AS) was developed for this evaluation. It is a multidimensional scale whose hypothetical structure is based on the references of teaching evaluative procedures and application evaluative research [4–7] and consists of 33 items, including both positively and negatively coded items, grouped into seven components (Table 1). The respondent rates the application on a five-point scale (from 1 – not true at all for these applications to 5 – completely true for these applications). The reliability and compactness of the scale are high: Cronbach alpha of the assessment scale EMD-GGA-AS (consisting of 33 items) is 0.90.
   - The assessment scale related to the use of the applications in the e-environment in the time of the pandemic crisis: the six additional items about the use of the GeoGebra applications in the e-environment and remote education in times of crisis.

Descriptive analysis, statistical procedures for a small sample, component/factor analysis and indi-

**Table 1.** The structure of EMD-GGA-AS

| Components (number of items) | Item examples |
|---|---|
| Technical characteristics (5) | The applications are well organized and visually transparent and obvious. |
| Realistic appearance, suitability, importance (6) | Realistic problems are presented in the software. |
| Harmonization with the objectives and outcomes of EMD courses (3) | The applications are in accordance with the course content and competencies that we need to acquire. |
| Interactivity (3) | We have the chance to independently investigate and design our own applications. |
| Contribution to motivation (3) | The software encouraged me to autonomously reach conclusions about the tasks. |
| Contribution to effectiveness (5) | Using this software made it easier for me to understand the content of the course. |
| Contribution to research behaviour improvement (5) | The applications are useful for autonomous students' work and learning. |
| Knowledge of GeoGebra concept and applications (3) | Software codes are open source and the users are able to modify them. |

cators of statistical significance were used for data processing in SPSS.

The small sample consists of 45 students of the electrical engineering module – power engineering undergraduate and graduate programmes at the University of Kragujevac, Faculty of Technical Sciences in Čačak, Republic of Serbia, where: 14 (31.8%) of them are third-year students, 18 (40%) are fourth-year students, and 13 (28.9%) are fifth-year students. Most of them (89%) had participated in some form of online courses before. Based on the nature of the curriculum, all students use computers and different software applications actively.

## 3. Results of the Evaluation of Educational EMD GeoGebra Applications

Students have a chance to use two groups of GeoGebra applications for EMD: the applications developed by the course teacher (more than 30) and the applications of other authors included in GeoGebra and suggested by the course teacher. While one-third of the students didn't use the software designed by the other authors (35.9%), two-thirds of the students did (they used at least one GeoGebra application specialized for EMD). All students used the course teacher's EMD GeoGebra applications: 11.9% used over 15 course teacher's programmes, 21.4% used between 11 and 15, 42.9% used between 6 and 10, and 23.8% used between 1 and 5 EMD GeoGebra applications.

The students assessed the contribution (effect or impact) of the developed EMD GeoGebra applications to their learning and exam results (Table 2).

The general assessment of the developed EMD GeoGebra applications (all used applications as a unique phenomenon) is high (Mean = 4.57) which indicates that this software is very useful during the learning process and passing exams. The best assessment is for the set of applications related to DC machines (DCM_C4 – C10). These applications created in GeoGebra are very important for understanding various DC machine characteristics. In professional literature, this kind of graphical characteristic derivation is very rare, but it is very convenient for later understanding of the synchronous generator characteristics. Since the students in their final exam must have one task related to machine characteristics graphical derivation, it was expected, as confirmed by the examination, that these applications are rated with higher scores.

The students' evaluation of the EMD GeoGebra applications is high. The mean on the assessment scale (EMD GeoGebra Applications Assessment Scale) is $M = 136.78$. The mean on the range of a five-point scale is 4.14 (Mean/Number of items = 136.78/33 = 4.14). Based on the mean of each item, the scores are between 2.45 and 4.93. The students assessed their knowledge of GeoGebra before the EMD courses as relatively low (Mean = 2.45). They assessed and recognized a high level of interactivity and the possibility to change simulation parameters (Mean = 4.93 on the five-point scale).

The assessment of eight educational aspects/components of the developed EMD GeoGebra applications is shown in Table 3.

**Table 2.** Students' assessment of the applications' contribution to learning and exam

| ***EMD GGA abbreviation*** | ***N*** | ***Min/Max*** | | ***Mean*** | ***Std. dev*** |
|---|---|---|---|---|---|
| *EF_C1* | 21 | 2 | 5 | 3.90 | 0.944 |
| *TR_C2* | 32 | 2 | 5 | 4.28 | 0.813 |
| *SM_C3* | 21 | 2 | 5 | 3.81 | 0.981 |
| *DCM_C4-C10* | 35 | 2 | 5 | 4.49 | 0.818 |
| *DCM_C11* | 33 | 2 | 5 | 4.30 | 0.810 |
| *DCM_C12* | 35 | 2 | 5 | 4.31 | 0.832 |
| *IM_C13* | 39 | 2 | 5 | 4.10 | 0.995 |
| *IM_C14* | 18 | 2 | 5 | 3.78 | 0.878 |
| *SM_C19-C20* | 25 | 1 | 5 | 3.84 | 1.143 |
| *SM_C22-C24* | 31 | 2 | 5 | 4.10 | 0.978 |
| *SM_C25* | 17 | 1 | 5 | 3.65 | 1.367 |
| *SM_C26* | 19 | 2 | 5 | 3.64 | 1.212 |
| *SM_27* | 18 | 1 | 5 | 3.83 | 1.249 |
| *SM_28-31* | 33 | 2 | 5 | 4.00 | 0.968 |
| *SPECEM_C27* | 8 | 1 | 5 | 3.50 | 1.604 |
| *SPECEM_C28* | 7 | 1 | 5 | 3.29 | 1.496 |
| ***All used applications*** | 35 | 2 | 5 | 4.57 | 0.655 |

**Table 3.** Students' assessment of the EMD GeoGebra applications educational aspects

| | ***Descriptive Statistics*** | | | | |
|---|---|---|---|---|---|
| ***Educational aspects\|components*** | *Min/Max* | | ***Mean*** | *Std. Dev.* | *Mean on 5-point scale* |
| *Technical characteristics (5 items)* | 17 | 25 | **21.62** | 1.652 | 4.32 |
| *Realistic appearance, suitability, importance (6 items)* | 15 | 30 | **24.86** | 3.098 | 4.14 |
| *Harmonization with objectives and outcomes of the EMD courses (3 items)* | 10 | 15 | **13.12** | 1.365 | 4.37 |
| *Interactivity (3 items)* | 11 | 15 | **13.02** | 1.244 | 4.34 |
| *Contribution to students' motivation (3 items)* | 4 | 15 | **11.53** | 2.594 | 3.85 |
| *Contribution to effectiveness (5 items)* | 5 | 25 | **20.64** | 4.282 | 4.13 |
| *Contribution to research behaviour improvement (5 items)* | 13 | 25 | **21.00** | 2.637 | 4.20 |
| *Knowledge of GeoGebra concept and applications (3 items)* | 5 | 15 | **10.84** | 2.600 | 3.61 |

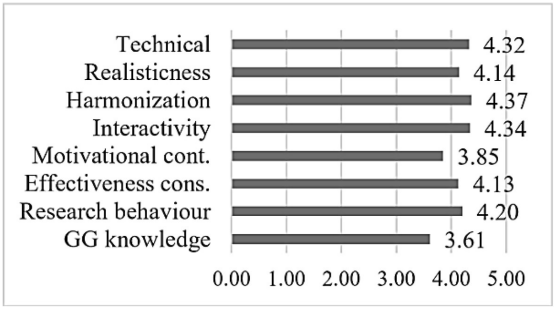


**Fig. 1.** Students' assessment of 8 aspects of the EMD GeoGebra applications.

The students perceived the technical characteristics of the EMD GeoGebra applications as highly realized. Harmonization with the course goals and programme interactivity were also assessed with high scores (Fig. 1). The surveyed students recognized the usefulness of GeoGebra interactive capabilities for the simulation of different physical phenomena, and engineering constructions, which is in accordance with the other research [8, 9]. On the other hand, they assessed the motivational contribution of the EMD GeoGebra applications and general knowledge of GeoGebra as software lower than the other components of the scale.

Additionally, the students assessed the applicability of these applications in the online instruction and remote learning environment. The results are shown in Table 4.

According to the students' evaluation, the EMD GeoGebra applications are very useful in the context of remote online university instruction.

The correlation analysis of the students' assessment of educational aspects/components of the EMD GeoGebra applications (Table 5) suggested that only the interactivity of the programmes correlated (statistically significant) with all the other components. The Pearson coefficient ranged from $r = 0.37$ ($p = 0.016$*) for interactivity and technical characteristics to $r = 0.59$ ($p < 0.00$**) for interactivity and knowledge of the GeoGebra software concept. Interactivity is an important component of the usability and quality of this educational software.

The sample of this evaluative research is small, and the comparison of the assessment of EMD GeoGebra applications between the students in different educational settings is not possible. It is the next step in the evaluation of the developed EMD GeoGebra applications.

In accordance with the students' evaluation of this educational set of applications developed for EMD courses at the Department for Power Engineering, the EMD GeoGebra applications are functional programmes to support students' in-classroom, online remote, and autonomous learning, and university teaching processes. The students perceived the applications as highly interactive and supportive, technically highly developed and adapted, and strongly harmonized with the EMD instruction

## 4. Conclusions

The two related articles (GeoGebra Tool: Development of Applications for Electrical Machines and Drives Teaching Support [1], and this article) are

**Table 4.** Students' evaluation of the use of the EMD GeoGebra applications in online remote instruction

| | ***Descriptive Statistics*** | | | |
|---|---|---|---|---|
| ***Online instruction aspects*** | *Min/Max* | | ***Mean*** | *Std. Dev.* |
| *Availability online* | 1 | 5 | **4.63** | 0.787 |
| *Downloading and offline work* | 1 | 5 | **4.19** | 1.029 |
| *Availability on different equipment* | 2 | 5 | **4.05** | 0.987 |
| *Availability through EMDA laboratory website* | 3 | 5 | **4.65** | 0.613 |
| *Suitable for remote online learning* | 4 | 5 | **4.78** | 0.422 |
| *Usability and utility in remote learning and teaching of EMD* | 4 | 5 | **4.75** | 0.439 |

**Table 5.** Correlation matrix of students' assessment of the educational aspects of EMD GeoGebra applications

| | ***Realistic-ness*** | ***Harmoniza-tion*** | ***Interactivity*** | ***Contr. to motivation*** | ***Contr. to effectiveness*** | ***Contr. to res. behav.*** | ***GeoGebra knowledge*** |
|---|---|---|---|---|---|---|---|
| ***Technical characteristics*** | 0.12 | 0.21 | 0.37* | 0.12 | 0.11 | 0.17 | 0.04 |
| ***Realisticness*** | | 0.22 | 0.48** | 0.75** | 0.53** | 0.69** | 0.55** |
| ***Harmonization with course goals*** | | | 0.47** | 0.24 | 0.22 | 0.27 | 0.37* |
| ***Interactivity*** | | | | 0.48** | 0.41** | 0.56** | 0.60** |
| ***Contribution to students' motivation*** | | | | | 0.63** | 0.74** | 0.45** |
| ***Contribution to effectiveness*** | | | | | | 0.57** | 0.50** |
| ***Contribution to research behaviour*** | | | | | | | 0.43** |

$N = 43$; *$p < 0.05$; **$p < 0.01$.

parts of the unique research approach and contribution to improving university instruction of electrical machines and drives.

Evaluative research on the effectiveness of EMD GeoGebra software in the university educational settings was presented in this paper. In accordance with the purposes of the applications' development, students of electrical power engineering have perceived and assessed these EMD GeoGebra applications as functional and powerful programmes to support their learning in different university teaching contexts and circumstances (in times of crisis, for example).

Although this evaluative research was realized as summative evaluation (after applications' development and implementation in the EMD courses), these results are the basis for further improvement of these applications and for the formative evaluative approach to the development of EMD teaching and learning supported by the educational software.

The EMD GeoGebra applications are available to the wider university population and can be accessed from any place and at any time by modern IT communication devices such as PCs, tablets or smart phones which boost applications attractiveness and makes teaching/learning process more feasible and interesting.

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