

Improving the Learning Experience of Neurodiverse Students in a Fluid Mechanics Course During the COVID-19 Pandemic

Ms. Caressa Adalia Wakeman, University of Connecticut

Caressa Wakeman is graduate student at the University of Connecticut (UConn) working in the Department of Civil and Environmental Engineering on the INCLUDE project. Caressa is currently studying education in the Department of Curriculum and Instruction and using her firsthand experience acquired during her undergraduate degree in Chemical Engineering to break ground in the field of Engineering Education. Caressa identifies as neurodiverse and is passionately committed to building community for neurodiverse students on the UConn campus.

Prof. Amvrossios Bagtzoglou, University of Connecticut

Amvrossios (Ross) Bagtzoglou is Professor of Civil and Environmental Engineering at the University of Connecticut. He received his Ph.D. in Water Resources and Environmental Engineering from the University of California, Irvine. His research interests include hydrologic modeling, estuarine and river water quality management, geostatistical simulation and probabilistic analyses. His current research projects are: 'Evaluation of Grid Resilience Activities with a Total System Performance Assessment Model' funded by Eversource Energy, 'PIRE: Food and Water Security in Ethiopia' funded by NSF, 'Cooperative Hydrogeophysics and Water-Resources Research' funded by USGS, and 'RED Innovation Beyond Accommodation: Leveraging Neurodiversity for Engineering Innovation' funded by NSF.

Dr. Maria Chrysochoou, University of Connecticut

Maria Chrysochoou is a Professor and Head of the Department of Civil and Environmental Engineering at the University of Connecticut. She obtained her BS in Physics at the Aristotle University of Thessaloniki, her MS in Environmental Engineering at Technische Universität Dresden in Germany and her Ph.D. in Environmental Engineering at Stevens Institute of Technology. She was hired as Assistant Professor at the University of Connecticut in 2007, promoted to Associate Professor in 2013 and Full Professor in 2019. Dr. Chrysochoou's general research area is environmental geochemistry, with a focus on site remediation, characterization and reuse of industrial waste and construction materials. Dr. Chrysochoou serves as the Principal Investigator of the project "Beyond Accommodation: Leveraging Neurodiversity for Engineering Innovation". Sponsored by the National Science Foundation Revolutionizing Engineering Department program, this 5-year project aims at transforming educational practices and cultivate the potential of neurodivergent individuals to contribute to engineering breakthroughs

Improving the Learning Experience of Neurodivergent Students in a Fluid Mechanics Course During the COVID-19 Pandemic

Abstract

The goals of this study were to assess whether the adoption of a comprehensive suite of inclusive academic interventions within a large engineering course (Fluid Mechanics) would increase the engagement of neurodivergent students enrolled in the course, and to observe whether or not students perceived the program interventions to be helpful. The course interventions were conceived and implemented within the broader context of the INCLUDE project which aims to transform the academic practices within the Department of Civil and Environmental Engineering at the University of Connecticut to embrace the unique strengths of neurodivergent students and improve the educational experience for all students.

Over the course of the semester, three surveys were handed out to students on a voluntary basis, one at the beginning of the course, one after the first and one after the second midterm exam. Of a class of 51 students, 50, 49, and 40 participant responses were received for the three surveys, respectively. Students were asked whether they identify as neurodivergent during the first survey; 10 out of 51 responded yes to this question. This study presents the responses received over time for two questions: the key challenges identified by students and whether they thought the course provided an effective learning experience.

Some of the emerging themes that were identified by the students as barriers were the difficulty of exams, advanced mathematics content, and course mode of delivery that was hybrid due to the pandemic. Themes identified as supports were alternate exam modalities, course content and delivery, lecture videos, TA/recitation videos, lab videos, and live-streamed lectures. It was found that on several occasions that students who identify as neurodivergent reported supports and challenges differently than the remaining students who responded to the survey. At the beginning of the semester, only 28.6% of neurodivergent student responses expressed a positive outlook on how effective the learning experience would be in this course. Interestingly, as the course progressed, 71.5% of neurodivergent student responses indicated that the course was providing an effective learning experience for them.

Introduction

The work presented in this paper was conducted under the auspices of the project “Beyond Accommodation: Leveraging Neurodiversity for Engineering Innovation” (abbreviated as INCLUDE), funded through the Revolutionizing Engineering Departments program of the National Science Foundation. The overarching goal of the project is to create a more inclusive learning environment for neurodivergent students, attracting and retaining a more diverse student body and empowering different kinds of thinkers to engage in engineering. Some of the cognitive differences we acknowledge that fall under the neurodiversity umbrella are anxiety, attention deficit hyperactivity disorder (ADHD), autism spectrum (AS), learning differences (i.e., dyslexia, dyscalculia, dysgraphia, and dyspraxia), and Tourette’s syndrome. The motivation for the project and underlying principle of the neurodiversity movement is that neurodiversity has unique benefits to offer society [1] and engineering problem solving [2]. We believe in a growth-mindset [3], positive psychology [4], strengths-based perspective [5] so we omit disability and disorder from our vocabulary and use terms like difference instead.

The INCLUDE project takes a holistic approach to changing academic practices, from recruitment in high school and transition to college, to career placement and employer outreach. A significant part is the systematic application of inclusive teaching standards (called I-Standards) in our curriculum. The I- Standards were inspired by the approach and format of Quality Matters, the certification system for online courses, which is adopted at the university for all online classes and is supported by the university teaching center [6]. They were developed by a team of faculty by integrating principles of Universal Design for Learning [7], evidenced-based inclusive teaching practices and a comprehensive suite of student support structures anchored by the strength-based approach. The I-standards are used as a guide to organize the activities of the I-team, a team of instructors who attend a series of workshops and work together to redesign their courses.

Research and evaluation activities in the project contribute to understanding the effect of inclusive academic practices on the perceptions and academic performance of neurodivergent students in engineering programs. This study was performed in the context of the evaluation of the interventions made in Fluid Mechanics, one of the first I-courses to be redesigned and offered in the department.

Setting and Scope of Study

Fluid Mechanics is a large, required course for juniors who major in Civil or Environmental Engineering at the University of Connecticut (UConn). Occasionally, Mechanical Engineering and Biomedical Engineering students take this course. The course covers basic fluid mechanics topics including hydrostatics, buoyancy, continuity, momentum and energy balance equations, pumps and turbines, Navier-Stokes equations, pipe network flows, and open channel flow. The course includes a laboratory component comprising four physical and two computational labs. The format of the course is a flipped classroom with laboratory and recitations sections taking place every week. However, during the pandemic the majority of the activities were on-line with in person interactions occurring whenever possible.

The enrollment for Fall 2020 when this course was implemented as an I-course for the first time was 72. A series of common interventions for all courses were implemented according to the I-standards. The syllabus was modified to declare the course as an I-course and

incorporate a personalized inclusivity statement by the instructor. All course materials including lecture slides and laboratory manuals were revised to meet accessibility standards as stipulated on the UConn Accessibility website [8]. Lecture videos, instructor's review sessions and TA recitation sessions were recorded and augmented with closed captions. During the first week of the semester, a short presentation was given to the class by the project manager and research assistant, including an overview of the project and neurodiversity, including strengths and challenges frequently associated with different forms of neurodiversity.

Beyond the standard interventions, other course-specific interventions were:

- Grade and performance anxiety was addressed by providing students with the option to replace one of the three midterm exam grades with the final exam.
- Alternate exam modalities were made available: oral exam, take home exam, design project exam.
- Videos showcasing the laboratory experiments being conducted were produced and captioned.
- Qualitative assessment of student performance was provided in narrative form as a supplement to quantitative marks for all course components.
- Students wrote two reflection pieces, one after each course unit, discussing challenges and how they address them; these provided suggestions on how the instructor could address their needs.

Despite the major changes effected in the course delivery, which always induces some anxiety, overall feedback from students through the Student Evaluation of Teaching (SET) was positive with 81% of the students judging the course as Excellent or Very Good and 80% of the students stating that they learned more or much more than their other courses. This feedback was almost identical to the last semester this course was taught by the same instructor before the pandemic. Therefore, the initial implementation of the I-course standards was considered a success for the first time offering of Fluid Mechanics.

The course was offered as an I-course a second time in Spring 2021 by the same instructor with the following modifications that were based on lessons learned during the initial offering:

- An oral exam modality was introduced in a more widespread offering (only a handful of students chose it during Fall 2020).
- A design exam option was offered earlier and as an alternative to midterms as opposed to only for the final.
- Lab-oriented TA office hours were offered during the weeks when lab reports were due and the students worked closely with the TA as they finalized their reports.
- The students wrote an extra strengths/challenges reflection piece at the beginning of the semester, which guided the assessment modality they pursued and was used to gauge how students' perceptions about the course evolved throughout the semester.

This study presents the evaluation of the student challenges and response to the different interventions implemented to address those challenges.

Instrument and Data Analysis

Description of survey

A detailed analysis of student perceptions on the course interventions was conducted using data collected using three reflection surveys implemented at three time points in the course in Spring 2021: the first week of the semester (Initial Reflection Piece), after the first midterm (Reflection Piece 1) and after the second midterm (Reflection Piece 2). The questionnaires used are shown in the Appendix; responses were collected anonymously by using surveys submitted over HuskyCT (the platform used for course interactions). Questions asked included prompts on what the students believed may give them difficulties, whether they have been classified as belonging to the neurodiversity spectrum, if the course has provided an effective learning experience, what was most helpful for their learning in this class, etc. Table 1 shows the number of responses collected for each of the three reflection pieces.

Table 1: A breakdown of the number of responses received for each reflection piece.

Reflection	Responses (n)
Initial Reflection Piece (IRP)	n = 50
Reflection Piece 1 (RP1)	n = 49
Reflection Piece 2 (RP2)	n = 40

The INCLUDE project research includes two hypotheses that were evaluated in the context of this I-course:

- 1) The department adoption of a comprehensive suite of inclusive academic strategies will increase the engagement and learning outcomes of neurodivergent students in engineering education.
- 2) Students perceive program activities as beneficial in terms of inclusion and engagement.

Specifically, the evaluation focuses on engagement of neurodivergent students, and of all students in the course, and their perceptions of the different interventions. Two evaluation questions are addressed in this study, as shown in Table 2.

Table 2: Overview of questions evaluated in the study

Question	Type of Question	Question in Survey
Student perceptions of challenges	Qualitative	Q1 IRP Q1 RP1
Learning Experience	Quantitative	Q3 RP1 Q2 RP2

Analysis of Reflection Pieces

After student survey responses were entered into Google Sheets the questions in Table 2 were selected for analysis. Quantitative questions had predefined responses that students could select from and a count of these responses, namely yes/no or specific categories were used for statistical analysis. The qualitative question (Q1) went through multiple iterations of coding that resulted in the emergence of themes. Initial codes were developed by identifying key phrases or by summarizing student responses and checked and recoded until themes among responses emerged as shown in Table 3.

Table 3: Themes developed for Question 1 in Initial Reflection Piece and Reflection Piece 1.

Emergent Themes	Codes included
Student condition	<ul style="list-style-type: none"> • Time management challenges, work overload • Study skills • Self-advocacy skills • Stress management
Course content	<ul style="list-style-type: none"> • Exam difficulty, pre-lecture videos, and homework. • Difficulty level of technical subject • Amount of material covered • Difficulty making connections between the content and specific problems and/or exams.
Course delivery	<ul style="list-style-type: none"> • Instructor effectiveness in the explanation of concepts, style of the lecture, the pace of course and relating which pieces of the course for were important to know for exams.
Remote learning	<ul style="list-style-type: none"> • Distractions due to an online environment, difficulty focusing, and a preference for in-person and/or synchronous lectures.
Missed sessions	<ul style="list-style-type: none"> • Includes missing synchronous lectures, not being able to make it to recitation sessions (office hours), or exam review sessions on a consistent basis.

Statistical Analysis: Comparing Proportions

Hypothesis testing on the student responses, expressed as percentages, is conducted with the z metric and a p-value is calculated and reported as $p_{>}$ or $p_{=}$ depending on whether it is a two- or one-sided test (Equations 1-3). $p_{>}$ or $p_{=}$ is used to test the inequality or equality of proportions, respectively. The statistical analysis was conducted with the internet based MedCalc software [9].

$$\hat{p}_X - \hat{p}_Y \sim N\left(0, \hat{p}(1 - \hat{p})\left(\frac{1}{n_X} + \frac{1}{n_Y}\right)\right) \quad (1)$$

$$\hat{p}_X = \frac{X}{n_X}, \hat{p}_Y = \frac{Y}{n_Y}, \text{ and } \hat{p} = \frac{X + Y}{n_X + n_Y}. \quad (2)$$

$$z = \frac{\hat{p}_X - \hat{p}_Y}{\sqrt{\hat{p}(1 - \hat{p})(1/n_X + 1/n_Y)}} \quad (3)$$

Results and Discussion

Student Identification

Out of the 51 students enrolled in the course in Spring 2021, 10 self-identified as having received one of the formal diagnoses under the neurodiversity umbrella, but only three had sought accommodations through the Center for Students with Disabilities. In the first week of the semester and prior to the first reflection piece being released, the project manager and a graduate student working on this project visited the class and made a detailed presentation about neurodiversity, the typical issues involved with neurodivergent students, and the

INCLUDE project objectives and initiatives. Approximately half of the class stated that they experience challenges similar to those typical of the neurodiversity spectrum.

For the remaining analysis, student responses were categorized according to their response to the question “Do you identify as neurodivergent?” Students who responded “yes” are grouped and referred to as such in the discussion, while all others are grouped and referred to as *neurotypical*. Hence, we use the term *neurotypical* to imply that the student has not explicitly self-identified as neurodivergent (even if this were indeed the case).

Student Perception of Challenges

Figure 1 shows the distribution of the codes developed for neurotypical and neurodivergent student perception of challenges as the course progressed. Only the top 3 codes in terms of frequency were analyzed statistically: Remote Learning (RL), Student Condition (SC), and Course Content (CC). The results of the statistical analysis are summarized in Table 4.

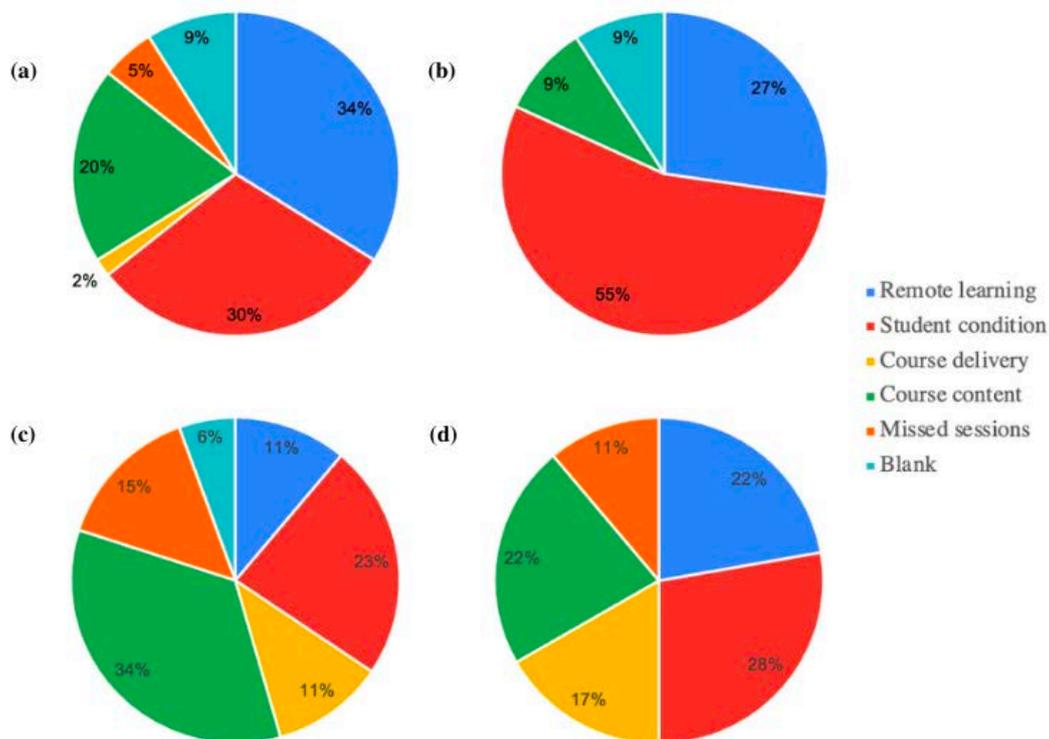


Figure 1: Student perceptions of challenges for neurotypical and neurodivergent students as the course progresses. Graphs (a) and (c) show the distribution of challenges for all students from IRP, Q-1 and RP1, Q-1, respectively. Graphs (b) and (d) show the distribution of challenges for neurodiverse students from IRP, Q-1 and RP1, Q-1, respectively.

Table 4: Proportions (%) of top 3 codes for student perception of challenges for neurotypical (NT) and neurodivergent (ND) students with course progression and p-value for hypothesis testing. A p-value in bold indicates statistical significance at 5% level.

	IRP			RP1		
	NT	ND	p _{>} or p ₌	NT	ND	p _{>} or p ₌
RL	35.6	27.3	0.37	9.2	22.2	0.035
SC	24.4	54.5	0.001	23.9	27.8	0.66
CC	22.2	9.1	0.035	40.0	22.2	0.028

	NT			ND		
	IRP	RP1	p _{>} or p ₌	IRP	RP1	p _{>} or p ₌
RL	35.6	9.2	0.0008	27.3	22.2	0.56
SC	24.4	23.9	0.95	54.5	27.8	0.0035
CC	22.2	40.0	0.028	9.1	22.2	0.036

At the beginning of the course, remote learning (RL) was considered an issue by roughly a third of the students, with no differences between neurotypical and neurodivergent students. As the course progressed and students were exposed to all the course tools developed in the INCLUDE project, neurotypical students no longer considered it an issue, whereas neurodivergent students still did at approximately the same proportion.

Student condition (SC) was identified as a key challenge for neurodivergent students initially, with half of them reporting personal issues as key source of challenges. This perception was mitigated later in the course, with about a third of neurodivergent students still reporting personal challenges in RP1. A quarter of neurotypical students perceived personal factors as challenges and this remained constant across the reflection pieces..

Course content (CC) was not considered a big challenge by neurodivergent students initially (possibly because SC dominated their perception); however, as the course progressed more students perceived its difficulty, with neurodivergent students less so when compared to neurotypical students.

Student Perception of Course Providing an Effective Learning Experience

Reflection Pieces 1 and 2 asked if the course had provided an effective learning experience with Agree (AG), Neither Agree/Disagree (NAD), and Disagree (DA). Table 5 shows the distribution of responses for all students and neurodivergent students and the results of the statistical analysis.

Table 5: Proportions (%) of codes for student perception of course providing an effective learning experience for neurotypical (NT) and neurodivergent (ND) students with course progression and p-value for hypothesis testing. A p-value in bold indicates statistical significance at 5% level.

	RP1			RP2		
	NT	ND	p _{>} or p ₌	NT	ND	p _{>} or p ₌
AG	47.6	28.6	0.026	62.6	71.4	0.41
NAD	37.9	57.1	0.028	34.4	28.6	0.58
DA	4.3	14.3	0.043	3.2	0	0.26

	NT			ND		
	RP1	RP2	p _{>} or p ₌	RP1	RP2	p _{>} or p ₌
AG	47.6	62.6	0.16	28.6	71.4	5×10⁻⁵
NAD	37.9	34.4	0.73	57.1	28.6	0.0036
DA	4.3	3.2	0.79	14.3	0	0.006

In RP1, only 28.6% of neurodivergent students agreed that the course provided an effective learning experience, compared to about half of neurotypical students. The difference between the two groups was statistically significant at 5% level. This percentage increased dramatically to 71.4% of the ND students at the time of RP2, i.e. the time between the first and second midterm was given. The percentage of neurotypical students that agreed also increased from 48 to 63%, however, that difference was not statistically significant.

Conclusions

At the beginning of the course, remote learning was considered an issue by a third of all students. As the course progressed and the course tools developed in the INCLUDE project became apparent, neurotypical students no longer considered it an issue, whereas neurodivergent students did in the same proportion. Student condition (challenges with self-regulation, mental health) was considered a major issue for neurodivergent students in the beginning but this changed dramatically later in the course. Only a quarter of neurotypical students perceived student condition as an issue and this did not change over time. Course content was not considered a big challenge by neurodivergent students initially (possibly because student condition dominated their perception); however, as course progressed and students realized its difficulty all students considered it a challenge, with neurodivergent students less so when compared to neurotypical students.

At the beginning of the semester, course perceptions were dissimilar between neurotypical and neurodivergent students; only 28.6% of neurodivergent student responses expressed a positive outlook on how effective the learning experience would be in this course. The neurodivergent students were significantly more than neurotypical students in their disagreement or indifference. However, a little after the middle of the semester perceptions had changed dramatically and were statistically equivalent for neurodivergent and neurotypical students. For neurotypical students perceptions did not change with time, with all three codes being statistically equivalent for the two time snapshots, whereas neurodivergent student perceptions improved greatly as course progressed (all three themes were statistically different). Overall, as the course progressed, 71.5% of neurodivergent student responses indicated that the course was providing an effective learning experience for them.

Acknowledgements

This material is based upon work supported by the National Science Foundation under IUSE/PFE: RED Grant No. 1920761. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Appendix: Questionnaires for Reflection Pieces

Initial Reflection Piece

- 1) Please articulate how you are attending the class, how you plan to study, what you believe may give you difficulties, and most importantly what steps will you take to tackle those perceived difficulties.
- 2) Please give me suggestions on what I can do to help you succeed in this class.
- 3) Have you been classified via formal diagnosis as belonging to the neurodiversity spectrum (Anxiety, ADD, ADHD, Autism, etc.)?
 - a. Yes
 - b. No
- 4) Do you feel that you experience challenges similar to those typical of the neurodiversity spectrum (Anxiety, ADD, ADHD, Autism, etc.) even though you have not been formally diagnosed?
 - a. Yes
 - b. No
- 5) Even though it is still early in the semester, do you feel that the changes I described and made in the delivery of this class (lecture videos, TA/recitation videos, lab videos, live-stream with Webex, alternative exam modalities) will enhance your learning experience?
- 6) Which of these changes (mentioned in #5) do you think will have the most positive impact on you?
- 7) Out of the three alternative exam modalities (2-hr take home traditional exam, oral exam, design mini-project exam), which do you think may suit you better? I understand this is preliminary and by no means “cast in stone.”
 - a. 2-hr take home traditional exam
 - b. oral exam
 - c. design mini-project exam

Reflection Piece 1

- 1) Please articulate how you are attending the class, how you are studying, what gives you difficulties, and most importantly what will you do differently in the future in order to improve your performance (if needed).
- 2) Please give me suggestions on what I can do better in order to help you succeed.
- 3) Overall, this course has (so far) provided an effective learning experience.
 - a. Disagree
 - b. Neither Agree nor Disagree
 - c. Agree
- 4) What has been most helpful for your learning in this class so far? (e.g., Describe the time(s) in this class when you were most engaged regardless of whether you attend in person or remotely).

Reflection Piece 2

- 1) Please give me suggestions on what I can do better in order to help your fellow students succeed in future offerings of this course. **Place emphasis** on critiquing me if I failed to follow up with my action items and/or your suggestions from prior reflections. Also, offer more suggestions for me as appropriate.
- 2) Overall, this course has (so far) provided an effective learning experience.

- a. Disagree
 - b. Neither Agree nor Disagree
 - c. Agree
- 3) Do you feel that the changes I made in the delivery of this class (lecture videos, TA/recitation videos, lab videos, live-stream with Webex, alternative exam modalities) enhanced your learning experience?
- 4) What has been most helpful for your learning in this class so far? (e.g., Describe the time(s) in this class when you were most engaged particularly because you attended remotely).

References

- [1] Rentenbach, B., Prislovsky, L., & Gabriel, R. (2017b). Valuing differences: Neurodiversity in the classroom: Drawing on their own experiences as students, researchers, and educators, the authors discuss how teachers can build on the skills and talents of neurodiverse learners. *Phi Delta Kappan*, 98(8), 59.
- [2] Esmaili Zaghi, A., Tehranipoor, M., & O'Brien, C. (2016). Major observations from a specialized REU program for engineering students with ADHD. Proceedings of the ASEE Annual Conference, New Orleans, LA. <https://www.asee.org/public/conferences/64/papers/17286/view>
- [3] Cavanagh, A. J., Chen, X., Bathgate, M., Frederick, J., Hanauer, D. I., & Graham, M. J. (2018). Trust, Growth Mindset, and Student Commitment to Active Learning in a College Science Course. *CBE Life Sciences Education; CBE Life Sci Educ*, 17(1), ar10. 10.1187/cbe.17-06-0107
- [4] Seligman, M. E. P. (2019). Positive Psychology: A Personal History. *Annual Review of Clinical Psychology; Annu Rev Clin Psychol*, 15(1), 1-23. 10.1146/annurev-clinpsy-050718-095653
- [5] Anderson, E. (2005). Strengths-Based Educating: A Concrete Way to Bring Out the Best in Students--and Yourself. The Confessions of an Educator Who Got It Right--Finally! The Quest for Strengths. *Educational Horizons*, 83(2), 180.
- [6] Chrysochoou, M., A.E. Zaghi, C.M. Syharat, S. Motaref, S. Jang, A.C. Bagtzoglou, and C.A. Wakeman, 2021, "Redesigning Engineering Education for Neurodiversity: New Standards for Inclusive Courses", 2021 ASEE Virtual Annual Conference, Content Access, Virtual Conference. <https://peer.asee.org/37647>.
- [7] CAST (2018). Universal Design for Learning Guidelines version 2.2. Retrieved from <http://udlguidelines.cast.org>
- [8] UConn (2022). <https://accessibility.its.uconn.edu/intro-creating-accessible-digital-content/>
- [9] MedCalc Software Ltd. Comparison of proportions calculator. https://www.medcalc.org/calc/comparison_of_proportions.php (Version 20.027; accessed February 1, 2022)