Breaking the Cycle of Memorization in Physics Education: Examining its Impact on Understanding and Scientific Education at TED Istanbul College

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Context

The physics education system in Turkey is an industry that is rapidly expanding. However, with the consideration of this increase, academics succeed in raising a major concern over the state of physics students and the education itself in this country of interest. The Program for International Student Assessment (PISA) 2018 results show that "Some 75% of students in Turkey attained Level 2 or higher in science (OECD average: 78%)". (OECD, 2019). "In Turkey, 2% of students were top performers in science, meaning that they were proficient at Level 5 or 6 (OECD average: 7%)"(OECD, 2019) From this it could be analysed that the percentage of top performers in Turkey in Science is much lower that the world average percentage. Also from "A study conducted by Yaşar and Mustafa Sözbilir, who are researchers from Atatürk University, called "Prospective Science Teachers' Views related to the Turkish Education System: Current Problems and Proposed Solutions" have concluded many problems with the scientific education given in this country with gathering quantitative data from 500 participants. Some of these problems involved lack of funding, inadequate textbooks and most importantly a non-scientific model of education. (Yaşar, 2017) The results of this study were proposed as a major reason why students under MEB education were failing. (like their scores in PISA exams) These data show that there is a major problem in the way science is taught to students in MEB education. However there seems to be a gap of experimental rigour in this field of research on why these problems are happening in this system with regards to the ciriculum. This text will prioritise the gap raised in the specific field of science, physics.

In the article written by Palema M. Ironside, published in Journal of Nursing education, called “Teaching Thinking and Reaching the Limits of Memorization: Enacting New Pedagogies” Palema argues that rote-memorization learning is the reason for failure of students in scientific fields such as medicine and nursing. The author further hypothesised that this could be the case for other scientific fields.(Palema, 2005) Following from their research is the question raised by this article if this state of scientific education in Turkey is somehow related with the over dependence on memorization and its effects on the students of the school of interest which is TED Istanbul College. The question is “How does the reliance on memorization in physics education in Turkey affect students’ understanding of physical subjects and their scientific education in TED Istanbul College?”

This paper has several implications for the field of science education. First, the study sheds light on the potential results of relying on memorization-based teaching methods in the current state of physics education in Turkey with its roots potentially connected to the major problems aforementioned in this article. This study can find rote memorization learning's negative impact on students' understanding of scientific concepts and their ability of applying them to real-world problems. The results of this study can result in higher ups from MEB to start implementing strategies in the favour of a new type of curriculum which is not memorization guided. By taking a comprehensive and nuanced approach to understanding the complex relationship between education curriculum and student success, this study can contribute to the cluster of rigorified quantitative data that can improve the quality of science education in Turkey and other countries facing similar challenges.

The basic structure of the experiment which will be conducted for this paper is giving out a demonstration of a physical phenomenon for two groups, one group who takes AP Physics which is characterised by a scientific approach on teaching and the other group taking MEB Physics which is characterised by a memorization guided curriculum. The study will ask the students to submit 50 to 100 word essays explaining the phenomenon and the study will compare the ability of the students in two different groups to apply their knowledge into real world phenomena. The initial assumption of this paper is that the participants in the AP Physics group will perform better than the participants in the MEB group since they are taught in a style that is less reliant on memorization. If this result is achieved it will be argued that since the groups did not differ in any sense except the curriculum they have been educated with, the memorization based approach when it comes to education of science, actively harms the students in TED Istanbul College and potentially students from the entire country.

The study will use quantitative measures of standardised testing of the students with an open-ended question which resembles FRQ's in AP system to assess the effectiveness of the different physics education approaches. The results of this research will provide important insights into the limitations of the MEB Physics approach, and how it compares to a scientific Physics instruction in terms of promoting student learning and understanding of physics concepts.

The biggest challenge of this experiment lies in its quasi experimental nature, which involves testing two pre-existing groups. Since these groups are not created from scratch, the initial differences of the prior physics knowledge of students can not be accounted for. This

could put the generalizability of the results at a stake. Ethical considerations in this experiment include ensuring that all participants are aware of the nature of the experiment and have given informed consent to participate.

Literature Review

The topic of memorization based learning versus scientific form of learning has been a debate that has been going on for the last century with many academics publishing many articles debunking eachothers research and theoretical findings. A study conducted by an associate professor in Ege University, Namdar Bahadır, called “Preservice Science Teachers' Understanding of Turkish Science Education Instructional Program” has found out that recent developments were made in scientific education of Turkey with making it more scientific based, however the teacher failed to adapt to these changes because of years of receiving and giving an education which is overly reliant on memorising facts. They “had limited understandings towards scientific literacy, assessment, scientific process skills, and socioscientific issues”(Bahadır, 2017) However after giving a form of scientific education they were observed to “increased their understanding towards scientific process skills and scientific literacy” (Bahadır, 2017) These data gathered from teachers only show that giving a scientific education to students not reliant on memorization is only a factor which would increase the critical thinking skills of both the students and the teachers. It is also only fair to mention that the lack of critical thinking implemented on students by teachers also made the teacher incapable and unskilled in their field when it comes to applying their body of knowledge. Therefore rote-memorization

techniques only led to worse teachers which by consequence actually led to even worse education for students.

Another study conducted by Hosseinzadeh Hassan, an associate professor from the University of Wollongong, called “Effectiveness of case scenario-based teaching to transition international Master of Public Health students specialising in health promotion from memorization to critical thinking” has found out that “Students [were] disadvantaged when required to demonstrate critical thinking mainly because of their previous training in memorisation.”(Hassan, 2022) The study concluded that it needed to adress “this need by evaluating the effect of case scenario-based teaching on transition from memorisation to critical thinking among international students”.(Hassan, 2022) The findings of this study were significant since they explicitly argued for an education system which discourages memorization. Also the effects of memorization based studying in the Asian background individuals found in this experiment showed that students who have received memorization based education in their background failed to adapt into scientific models of education which promote critical thinking in the West and have failed to develop critical thinking skills. This study is further proof that memorization based teaching is not an adequate way of teaching. The works of Yaşar complement this study. They also nationalise the phenomena to Turkish education with the quote “Inability to ensure higher-order thinking skills among students in science education (research, questioning, analysis, synthesis, etc.) [was found]”(Yaşar, 2017).

Ben Orlin, the author of the famous book series “Math with bad drawings”, in his article called “When Memorisation Gets in the Way of Learning” has argued that memorization of facts

of students has declined their attention spans and therefore is not a very complete way of teaching. He realised that his students were unaware of basic maths concepts like what the sine of an angle is as he can be quoted “So I skipped ahead, later to realise that they didn't really know what "sine" even meant. They'd simply memorised that fact.”(Orlin, 2018) He realised that maths did not mean anything to his students and the concepts in maths were out of the students’ minds. He can be further quoted “To them, math[s] wasn't a process of logical discovery and thoughtful exploration. It was a call and-response game. Trigonometry was just a collection of non-rhyming lyrics to the lamest sing-along ever.”(Orlin, 2018) From his words it is apparent that students lacked the understanding of logic in maths since they have been raised with an over reliance on memorization, signalling that memorization reliant form of education fails the students.

Further research of Edvin Schei, a medical teacher from the University of Bergen who specialises in qualitative data analysis, in his article “Trustingly bewildered. How first-year medical students make sense of their learning experience in a traditional, preclinical curriculum.” involved testing 40 medical students on their critical thinking skills. Medical science is a field characterised by an over-reliance on memorization and the results were devistating. He had found disconnected knowledge, lack of critical thinking, unmotivation and an isolation of students from both the society and their fields of interest.(Schei, 2018) Dr.Schei can be quoted “The students found it hard to learn a huge amount of theoretical facts without seeing the ‘links and connections’ to clinical medicine.”(Schei, 2018) From this it could be analysed that simply memorising the facts fails students in painting the big picture in their minds and makes them have disconnected knowledge which they do not know how to apply. This results in a generation

of a work force being generated which is filled with people who have no idea how the material they have studied in the university has anything to do with each other or their jobs.

A study conducted by Alieh Nasrollahi-Mouziraji, the research team leader in the Islamic Azad University, called “memorization makes progress” has argued “Rather than considering rote memorization as a direct opposition to understanding, it can be viewed in a complementary role”. (Mouziraji, 2015) According to Alieh Nasrollahi-Mouziraji a child develops memorization skills much earlier than it does critical thinking skills and therefore memorization of facts can lead to a better conceptual understanding of the topic the child is studying. According to him, memorising facts can strengthen the intelligence of children as he can be directly quoted as saying “through memorising[] the network of neural connections which build the foundation of raw intelligence is strengthened.”(Mouziraji, 2015) Also Neumen Dave, an award winning historian, in his aritcle “In Defence of Memorization: The Role of Periodization in Historical Inquiry” argued that memorization played a major role on actually helping students see the big picture and provide a background which they can build conceptual understanding on top of.(Dave, 2011) What these two sources arguing in favour of memorization fail in, however, is providing actual data besides theory about how memorization actually helps understanding. They are excellent theoretical texts however there is no rigorous research which has gathered quantitative or qualitative data in favour of memorization being an adequate way of learning, while much qualitative and at least some quantitative data has been provided against memorization

In conclusion the academics are divided into two fractions for this topic. There are educators who argue that education needs to stop relying on memorization and that this act of learning is practically harming the understanding and application capabilities of students. Then there are researchers who argue that memorization needs to be used as a powerful tool inorder for better understanding and that memorization helps accelerate the learning capabilities of students. The reason for these disagreements in this field can be attributed to the lack of rigorous experimentation for this topic and the authors' over reliance on the theory of education rather than the experimental analysis. While there is much qualitative data in this field at least against memorization, there seems to be a lack of quantitative data on both sides of the argument. This is unexpected since the topic is essentially about physics at its core which is a science which promotes experimental data. However it can be thoroughly seen that the researchers simply overlooked experimental analysis to answer the debated question. This will be the gap acknowledged in the literature of this topic in this paper. The gap is that there is no rigorous data to test if memorization based study of science is better or worse in the literature, so in other words comparing the two approaches of teaching. This paper seeks to close this gap by performing a rigorous experiment with two groups educated on the same topic under opposing programs. The object of this paper is to at least start rigourifying a part of this education research, the part of physics education.

Methods

It was aforementioned that the aim of this paper was to close the gap of lack of experimental rigour in this field. Therefore an experiment needs conduction for the paper. The

way this experiment will be conducted is as follows. In TED Istanbul High School, physics is offered in two seperate forms, one being AP Physics which is mostly characterised by being rigorous and scientific. As College Board can be directly quoted:

> Based on the Understanding by Design® (Wiggins and McTighe) model, this course framework provides a clear and detailed description of the course requirements necessary for student success. The framework specifies what the students must know, [] and understand, with a focus on six big ideas that encompass core principles, theories, and processes of physics. The framework also encourages instruction that prepares students to make connections across domains through a broader way of thinking about the physical world.(2023)

with regards to the education style of this course. Another form of physics offered in TED Istanbul Highschool is the MEB physics or regular physics which is mostly characterised for its over-reliance on memorization. This can be shown with the findings of Yaşar with respect to the science education in Turkey, “Theoretical and rote learning- teaching activities in science education (dominance of the traditional approach…) and inability to ensure permanent learning [was found] ”.(Yaşar, 2018) From the ideas of people and organisations who create these education systems, It can be argued that the MEB education system is a good representation of a memorization reliant education system while AP Physics is an accurate representation of a rigorous/non-memorization based education system.

The steps of this experiment is to group the students into two groups of 20 each. The first group will be made of students who take AP Physics and the second group will be made out of students who take MEB Physics. The experiment design is quasi-experimental because the experiment will be comparing two groups of students (AP Physics students and MEB Physics students) that are already made. In true experimental designs, participants are randomly assigned to groups, but in this study, the paper will be using pre-existing groups of students who are already enrolled in different types of physics classes. Therefore, the paper will not have control over the selection of participants, which is a sign of quasi-experimental designs. A Quasi-experimental design is the most suitable one for this experiment since these two groups already exist in the natural TED environment and creating, raising new students will consume time and funds that are better spent on research. Creating new artificial groups would both interfine with the results in this case since the students would be taken away from their natural TED environment, therefore not showcasing the effects of memorization based learning on TED students as intended and it would be a waste of time since already made groups can be acsessed. Therefore the quasi experimental design is the most appropriate for this experiment. The sample size of 40 people is acceptable for representing %50 of TED's physics students of 80 members. The studies approach is an explanatory approach, an approach defined by explaining the complex relationship between variables. This is because the study is comparing the abilities of students in two different groups (AP Physics and MEB Physics) and seeking to explain the differences in their performance. It is also because the experiment seeks to clear up the connections between memorization heavy learning and student success and not to discover new connections between these subjects, which would require an exploratory approach to be taken. Also a creative

approach will obviously not be used since there is no viable physical product that could be created as a solution for the theoretical and abstract problems raised in this project.

After the participants have been selected, they will be given a demonstration of a physical phenomenon of a rope. The rope will be swung in a circle, and to the surprise of the participants, the end of the rope will rise into the air without any force being applied on it. Then the participants will be left to explain how this happened with the physical knowledge they gained throughout the year on Newtonian kinematics and dynamics in a short, 100 words, paragraph. The real reason why this phenomenon occurs is that the rope is swung in an angle with respect to the horizontal x-y plane which results in a component of the tension of the rope in the z direction which can be formulated as the value of tension times the sine of the angle with respect to the horizontal. This component of the force results in a net change in position of the rope, or in other words it causes it to rise with no, apparent, force on it. The students who manage to write anything relating to the tension component in the z direction will be rewarded with a 4/4 score. Students who explain it with a centrifugal force acting on the rope will get 3/4 since this force is not a real physical phenmenon. The students who mention the tension in the rope, however do not mention its vertical component or who mention anything relating to inertia, will get 2/4. Students who connect the phenomenon to air friction or Newton's third law of action-reaction with air, will get ¼. The students who write anything else will not be scored (will be scored 0/4). The reason why a one question, interactive test is picked rather than a conventional one is to minimise the unfair advantage of AP Physics students performing better since they have more experience on solving traditional questions. Since this type of real-world applicable question is new to both groups, this unfair advantage of experience will be eliminated and since the question

is generated specifically to test the conceptual understanding of students, this question will perform better on accurately testing the understanding of the physical phenomenon than standardised tests would do. This question based format has been adopted from the work of Edvin Schei, who has conducted questionnaires to medical students with succeeding results. (Schei, 2018) The students will sign the papers for their informed consent and their papers will be kept anonymous with no names written in order to maintain the students' privacy and safety. The method type of this experiment is quantitative. Quantitative methods are defined as methods which value numbers of participants rather than the quality of participants to maximise the participant rates. The aim for selecting a quantitative type for data is to get more numbers for higher accuracy in results. Also it ties with the main aim of the paper of establishing experimental rigour in a field who lacks it. Quantitative data type helps establish more rigour in a field with greater numbers of participants and subjects. Also there seems to be a plethora of qualitative data already in this field of study which was discussed in the section Literature Review, where there seems to be a lack of quantitative data which this experiment seeks to close the gap of. Quantitative data will be gained from the scores of the students by being taken an average of and then compared between the groups. Also the number of students who have achieved a full score in the specific groups will be compared in the results section. The instrument of this project will be the demonstration of the physical phenomenon with the rope and the essays that the students will write. In order for a scientist to replicate the experiment, they have to again divide the students into two groups and formulate a new physical phenomenon, instruct students to write essays explaining the phenomenon and have a grading system based on potential responses. Then they need to average out the scores and compare the performance of two groups.

Results

The results of the experiment (Figure 1.1) complied with the hypothesis. Firstly it is only justified to note that all AP Students consented to join the experiment while only 14/20 of MEB students agreed to join the experiment. Out of these 14 students, 6 of them submitted answers which were classified as not being worthy of scoring. Out of these 6 students, four of them responded with actual explanations of the phenomenon while two students decided to respond by writing inappropriate slurs which are quite obviously irrelevant with the experiment. There were no AP students who submitted such inappropriate content, which is a worthy thing to note. 2 other students from the MEB team responded with answers relating to air friction which were scored ¼. 2 other students responded with the explanation of Newton's first law (inertia), which was scored 2/4. 4 students explained the phenomenon with centrifugal force, which was scored ¾. Finally, no student in the MEB team managed to land on the actual result which meant that no one managed to get a full score. The overall average of MEB students was 1,285/4.

None of the AP students responded with offensive slurs or refused the experiment. Also none of them wrote answers which were deemed to be unworthy of a score. Surprisingly none of them connected the phenomenon with air friction, which resulted in, again, no one receiving a score of ¼. Much like the MEB team there were only 2 students who decided to explain the phenomenon with inertia, which made them receive scores of 2/4. Astonishingly, 16 students in the group of 20 decided to explain the phenomenon with centrifugal force, a concept which is barely explained in the AP system. However 2 students managed to explain the phenomenon

with the vertical component of the tension which made them get full points. All of this led to the class average of ¾.

	Not scored	1/4	2/4	3/4	4/4	Average Score
MEB Students	6	2	2	4	0	1,285
AP Students	0	0	2	16	2	3

Figure 1.1

Discussion

The results were significant. Before the experiment it was not expected that AP students were all going to fall into the trap of centrifugal force. This is since the AP Physics curriculum does not extensively teach this topic while MEB curriculum is known to teach it. It was originally expected that MEB students would respond with centrifugal force more often than AP students however this failed to be the case. Perhaps the reasoning behind this observation could be further studied in the future.

However even if the results were not completely as expected, they did correspond with the hypothesis which stated that AP students would perform better in a real life application of physics. This was the case, since AP students scored higher than twice the score of MEB students, surpassing MEB students with a ¾ score (as opposed to the 1.285/4 score of MEB students). Also none of AP students scored below 2/4 while 8/14 MEB students responded with below %50 scoring answers which is an indicator that AP Physics students are less likely to fall into low-scoring traps. Also it is fair to note that 6 students in the MEB team failed to consent to the experiment showing a lack of interest and engagement in physics while all of AP students consented to the experiment. Also 2 students in the MEB team decided on performing an act of treason for the experiment, by replying with unaccaptable slurs on their forums. This lack of motivation for a physics related experiment in MEB students could be studied in the future with its roots potentially connected into rote-memorization based learning. However, for now, it will be accepted that this was a result of a system which is over-reliant on memorization. Facts of; AP students scoring better than MEB students, AP students not scoring below 2/4 while MEB students failed to correspond to the statistics of AP students, more compliance on a physics related experiment by AP students and 2 AP students scoring full points in the experiment opposed to zero students in the MEB team, indicate that the AP curriculum better prepares the students to real life applications in physics and the understanding of physical phenemenon. The fact that MEB students were so uninterested in the study actually aligns with the works of Edvin Schei who had concluded that over-reliance on memorization caused unmotivation and isolation of students.(Schei, 2018) Also the failure of MEB students actually can be tied with the work of Ben Orlin who has inspected that memorization based learning results in students not comprehending fundamental concepts (Orlin, 2018), which could have been the reason why

MEB students failed in an experiment requiring the understanding of fundamental concepts of dynamics and kinematics. AP curriculum was previously established as a system which does not really overly depend on memorization, MEB system was established as a system of over-reliance on memorization and this test was proven to be a valid test when it comes to testing the understanding of students of physical subjects(also critical thinking and abilities of real world appliaction), it could be argued that the over-reliance on memorization in physics education in Turkey harms students' understanding of physical subjects, skills of critical thinking and their abilities of scientifically explaining physical phenomena at TED Istanbul College.

The biggest limitation experienced in this experiment was by the MEB students' unwillingness to perform the experiment, which could have been patched if a teacher performed the experiment under the name of a pop-quiz which would affect the grades of the students. It is highly suggested that this would have improved the marks of MEB students. Also a potential misunderstanding of the results of the experiment could be that the students in the AP physics course could be just overall better performing students than the students in the MEB team which could be the reason why they performed better and would highly put the results of this experiment in danger. Another potential interpretation is that since the teachers teaching MEB and AP physics are different teachers, the teacher who is teaching AP Physics could just be a more successful teacher which would attribute the success of AP students to the teacher rather than the education curriculum. This study has just simply explained the need for rigorous experiment in this field of study. This paper is only written as a pseudo-tutorial on how and why to perform future experiments in the research for physics education and is not funded with nearly

enough money to actually establish undisputable data. Therefore the results of this study are to be replicated if wanted to generalise its findings.

So in the future this subject of MEB education versus AP education can be studied even outside the scope of Physics. The reason behind the baffling centrifugal force disaster encountered in this experiment can be further studied. Also the under-compliance of MEB students in the experiment could be investigated in the future with its roots potentially connected to the topics discussed in this paper like the over-reliance in memorization.

Implications, Limitations, and Future Research

There are an unfortunate number of limitations when it comes to the experiment conducted for this paper. Firstly and most importantly even if the question that was asked to the students was originally generated by the experimentalists of this article and was not copied or taken from a physics source, there is a possibility that a student by complete chance thought of this question or any other question relating similar phenomenon before and already had a rough answer. Although the chances of this happening is not very high, it is still worth considering. Secondly, even though students were selected to have similar educational backgrounds (the same highschool), some of the students in AP Physics could be going to cram schools or in general studying harder for their course. This would undoubtedly unfairly increase their success rate in this experiment and also would be an outside factor which could have caused the baffling centrifugal force related submission rates of the AP team. This is a limitation of the research conduction by quasi-experimental design since in this design the outside factor and the

participants could not be controlled. This could have been fixed if a pure experimental design were to be adopted. However it was not, making it a limitation. Thirdly, the teachers who are involved in AP Physics and MEB Physics are different. The quality of the teachers may have influenced the understanding of the physics concepts in students, which could have generated better or worse outcomes in averages for the separate groups. The fluctuations of teacher quality would have nothing to do with the teaching methods, therefore being an outside factor which can not be controlled, or to put it in a slightly different form; a limitation. Another limitation is a potential Hawthorne effect where the students did not perform in their full capacity since they were informed that this was an experiment rather than a quiz or a test. Maybe if a teacher performed this experiment as a quiz rather than a classmate, this effect could have been completely eliminated. However in this paper; it was not, making it a limitation.

Future research could actually fix these issues by not performing a quasi-experimental method, but a pure experimental method. These studies can be done by taking two groups who have no idea on physical concepts and teaching the two groups with different teaching styles, then making them take a test with not one but multiple questions and only then comparing the results. This will get rid of limitations of outside factor control such as potential cram schools which have plagued this experiment. Ideally these studies will have the same teacher teaching the two groups and even more ideally to get rid of the Hawthorne effect, the students will be tested in regular test/exam format with no idea that they are in an experiment. If these conditions are met the possibility of students having unfair outside education, the teacher quality being non consistent throughout the groups and the students not showing one hundred percent of their capacity will be mostly eliminated. The reason why this quasi-experimental was adopted in this

study was simply the lack of budget and since the study asks the effects of a memorization based curriculum on the TED environment. However, future research could actually fix this with additional funds and border research questions.

This study, while it has limitations, has many implications for the future. If researchers actually realise the gap or experimental rigour in this field concerning education, the methods and results of this study can apply to more general STEM fields, one of them being medicine. If the rote-memorization learning style is rigiroufied on being an inadequate system of education, then higher ups from MEB could actually realise that something is to be done with respect to the education system which could cause a slight reform in the education system if the higher ups decided on having counselling/assistance from the educators of college board who educate under a system which is proved in this study(and can be further analysed by future researchers) to be a system which prepares its students overall better than MEB does. Also the results of this study can apply to more major countries outside Turkey with similar issues in their education systems such as Saudi Arabia and India, and maybe could also be further analysed for the circumstances of those countries and be implemented on.

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