Personalizing Persuasive Educational Technologies to Learners' Cognitive Ability

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Abstract*—Persuasive Educational Technology (PET) is an effective tool for engaging students and promoting learning, using various persuasive strategies. Research has shown that personalizing PET could increase their effectiveness at engaging students and promoting learning. Cognitive ability has been identified as an important factor that could lead to individual differences in learning. Yet, there is a gap in knowledge on how learners' ability on various cognitive dimensions identified by Bloom's Taxonomy, is associated with their susceptibility to distinct persuasive strategies often used in PETs designs. To fill this gap, we conducted a large-scale study of 402 students to investigate how their cognitive ability scores relate to their susceptibility to persuasive strategies (*Reward, Social Learning,* and *Trustworthiness*) that are commonly used in PET design. We assessed the Cognitive ability scores using the test questions adapted from the Educational Testing Service (ETS) Kit. Our results show that there is a relationship between individuals' cognitive abilities and their susceptibility to persuasive strategies. People with high ability to *Remember* and *Evaluate* concepts are more susceptible to the *Reward Strategy*, while those high in ability to *Understand* are positively associated with the *Trustworthiness Strategy*. Similarly, we uncovered that individuals high in the ability to *Apply, Analyze,* and *Synthesize* ideas are positively associated with the *Social Learning Strategy*. These findings can guide PET designers on how to develop PET tailored to learners belonging to different cognitive ability dimensions.

Keywords*—*Persuasive Technology, Education, Personalization, Bloom's Taxonomy, Persuasive Strategies, Cognitive Ability.

I. Introduction

It has been widely acknowledged that Information and Communication Technology (ICT) can be used to impact positively teaching and learning in general [1] and engineering and computing specifically. Persuasive Technologies (PTs) are special types of ICT designed to promote desired behavior change [2]. PTs have successfully been applied to promote positive outcomes in many domains, including education (for example see Lucero et al. [3]). Persuasive Educational Technologies (PET) are PTs used in the education domain to engage students and promote active learning, using various persuasive strategies [3]. For example, some PETs have been designed as mobile applications [4], games [3] and robots [5]. One distinct feature of computer-based learning compared to other media is interactivity. Through this feature, PETs facilitate engagement in class activities, peer-interaction, active learning that leads to an attitude or behavior changes in a desirable direction [3, 4, 5]. This concept of PET is supported by the *Socio-Constructivist learning theory.* The Social Constructivist pedagogical paradigm stresses that "*social interactions are critical, and that knowledge is constructed via the interaction with the environment and the people"* (p.12) [17]. The theory suggests that to facilitate learning, a community of learners should engage in activities together, discourse, and reflect.

However, for these PET systems to be effective, they need to be tailored to the target audience [6]. Increasing empirical evidence have shown that Personalizing PTs to users' preference can increase their efficacy [7][8]. As a result, research has begun to investigate factors that could moderate an individual's susceptibility to persuasion. For example, Orji et al. [9] showed that culture is an important factor for personalization while Oyibo and Orji [10] showed that the five personality traits are important factor for personalization. However, most existing research on personalizing PT have been focused on domains other than education (e.g., promoting healthy behavior [8][6][7]). The lack research on how to tailor PET is a major drawback. For example, in engineering education, many e-learning materials are static in nature. E-learning materials must be designed to be interactive and adaptive to the target users. Several research have emphasized the need for student-centered pedagogy [11][12][13]. This is because when learning is optimized and tailored for learners, they become more meaningful and relevant, thus leading to greater engagement and improved learning outcomes.

To personalize PETs, factors that very closely influence how students learn need to be considered. Cognitive ability has been identified as an important factor that could lead to individual differences in learning. For instance, some students remember information more easily than others, while some students evaluate information better than others [11]. Each student has different intellectual capability and what triggers them to learn. These different intellectual capabilities have been well defined by Bloom's taxonomy of learning. In early 1956, Bloom classified behaviors believed to be important for learning. His work divided educational objectives into three domains – Cognitive (knowledge), Affective (attitude) and Psychomotor (skill) [12]. This means that after a learning episode, the learner should have acquired a new skill, knowledge and/or attitude. There are three main purposes in

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which Bloom's taxonomy has been used to fulfill. Firstly, to provide a set of objectives that educators could set for learners. Secondly, to help educators focus on all three educational objectives, thereby creating a more holistic form of education. Thirdly, to categorize skills needed for the objective into hierarchy, such that the higher-level skills are more complex than the lower-level skills [12]. Amongst the three domains, the Cognitive domain is the domain educators link mostly to learning. The Cognitive domain is the mental skill domain where learners process information, create knowledge, and think. Yet, there is a gap in knowledge on how learners with varying cognitive ability as identified by Bloom's taxonomy of learning, respond to various persuasive strategies that are often used in designing PET. Understanding how differences in cognitive ability relate to students' susceptibility to persuasive strategies, is vital to the success of PET.

To fill this gap, we conducted a large-scale study of 402 students. The study investigates how student cognitive ability, on different Intelligent Quotient (IQ) dimensions, relates to their susceptibility to persuasive strategies. We assessed student IQ using test questions adapted from Educational Testing Service (ETS) and their tendencies to comply with three strategies (*Social Learning, reward,* and *Trustworthiness*), that are commonly used in PET design using the Persuasive Inventory (PI) scale. We analyzed the continuous relationship between individuals' cognitive ability scores and their susceptibility to persuasive strategies. Our results show that there is a relationship between learners' scores on different cognitive ability dimensions and their susceptibility to persuasive strategies. Individuals with high ability to *Remember* and *Evaluate* concepts are more susceptible to *Reward strategy*, while those with high ability to *Understand* are positively associated with the *Trustworthiness strategy*. Similarly, we uncovered that individuals high in ability to *Apply, Analyze,* and *Synthesize* ideas are positively associated with the *Social Learning Strategy*. These findings can guide PET designers on how to develop PET tailored to learners belonging to different cognitive ability dimensions to increase their effectiveness.

Our work offers three main contributions to the Frontiers in Education and personalizing persuasive educational technology communities. First, we reinforce the need to *personalize* persuasive educational systems by revealing that learners of different cognitive abilities respond differently to distinct persuasive strategies. Second, we establish that the cognitive ability is an important characteristic for personalizing PETs and selecting appropriate persuasive strategies. Third, we compare the susceptibility to individual strategies of learners with different cognitive ability and develop design guidelines for personalizing PETs to individuals based on their cognitive ability. To the best of our knowledge, this study is the first to investigate the relationship between learners' cognitive ability dimension and their susceptibility to distinct persuasive strategies. This is an essential step toward developing personalized PETs that will effectively engage learners and promote learning.

II. BACKGROUND

In this section, we provide a brief review of the three PT strategies that we investigate, we also present an overview of cognitive ability dimensions as described by Bloom [14].

A. Persuasive Strategies

Persuasive systems achieve behavioral change by using techniques that are known to influence human behavior. These techniques are known as persuasive strategies. Today, there are several persuasive strategies that PT researchers integrate into persuasive system designs. For example, Fogg [2] described seven persuasive strategies – *Reduction, Tuning, Tailoring, Suggestion, Self-Monitoring, Surveillance, Conditioning* – that could be employed to motivate desired behaviors and attitudes. Oinas-Kukkonen and Harjumaa [15] built on Fogg's strategies to develop 28 strategies. These strategies have been widely used by PT researchers. For this study, we investigate the three persuasive strategies *Reward, Social learning* and *Trustworthiness* adopted from Oinas-Kukkonen and Harjumaa [15]. We chose these three PT strategies because they are very relevant in the context of learning. For example, one of the learning outcomes, which may motivate students to learn and work hard, include the reward they will gain from learning. Reward could be in the form of good grades, social recognition, or monetary prizes. Moreover, we believe that learning from others, such as peers, is an integral part of the learning process (Social Learning). Again, learners are often more motivated to learn from trusted sources (Trustworthiness).

1) Reward Strategy

The reward is a persuasive strategy that involves recognizing the achievement of individuals as they make progress towards performing the desired behavior [15]. Generally, people find it motivating when they receive incentives in recognition of their performance. The Reward persuasive strategy stems from the *Reinforcement theory* and *Behaviorist learning theory* which hypothesizes that learning could be influenced by physical variables such as rewards [16]. The behaviorist theory operates on a principle of "stimulus-response" [17]. That is, all behavior is caused by external stimuli. This theory assumes that if students are given the right stimuli, then the student will give the desired response. The Reward strategy is mostly implemented in learning systems as badges, points, grades, and rank increase as learner's advance towards achieving their learning goal. Most online learning systems use the Reward strategy to keep learners engaged and motivate them to learn.

2) Social Learning

The Social Learning persuasive strategy provides opportunities for learners to observe the behaviors of others (especially successful learners) with the aim of motivating them to imitate and model their behaviours against successful people [15]. It is derived from the *Social Learning theory* [17], which posits that "*learning is a cognitive process in which people learn by observing the behaviors of others and their consequences in a social context*" (p. 281) [18]. In persuasive systems, the Social Learning strategy can be implemented in various ways. For example, in PETs [5], sharing scores, decisions or methods used by successful learners to solve problems may inspire other learners and motivate them to perform better. [19].

3) Trustworthiness

The Trustworthiness persuasive strategy is based on the principle that a system that is viewed as trustworthy will be more effective at motivating learners. Often PETs provide a way to make an individual trust the system, the instruction delivery approach, and the learning material to motivate them to learn using the PET [15]. Hence, PETs need to be relied on as honest and truthful for it to motivate the desired learning outcome.

Several PETs have employed these persuasive strategies to motivate learning. For example, Lucero et al. [3] designed a PET to promote “reading habit in children between 8 and 11 years of age by motivating them to improve their reading and writing skills”. Their PET employs Trustworthiness as one of the persuasive strategies to motivate intended learning outcome. To gain the trust of users (children), they used a credible literacy character (papelucho), which is a well-known Chilean literacy character for children, that appeal to many of the target audience of PET. Similarly, Mintz et al.[20] developed a mobile PET for the HANDS Project to help young people learn social skills. They employed Reward and Social Learning strategies to motivate and help them learn and achieve a higher outcome than they would have otherwise.

B. Personalizing Persuasive Technologies

Research [6][7][21][22] has shown that adapting persuasive applications to the personal preference, ability, and disposition of the user increases their effectiveness. Personalizing PTs agrees with “Bruner’s theory of instructional scaffolding” [17], a part of the socio constructivist theory of learning; where learning is tailored to the needs of the student with the intention of helping them achieve their learning goal. Kaptein [7] identified two key personalization methods: *explicit* and *implicit* profiling. Explicit profiling is a meta-judgmental measure of the responsiveness of individuals to certain persuasive strategies. It is based on the standardized questionnaire scores of users. Usually, in user studies, individuals are asked to report, subjectively, judgments about their preferences and behaviors priori to inform the actual persuasive system design. On the other hand, implicit profiling is an operative measure of the traits of the user. It is based on the actual user-system interactions and user responses to persuasive attempts. In most cases, explicit profiling is the first step towards personalizing PET while implicit profiling is used to further refine the systems. The operative measures are directly linked to the cognitive processes that underlie persuasive responses.

Over the years, with respect to explicit profiling, several measurement scales have been developed, by researchers, to elicit individuals’ susceptibility to distinct persuasive strategies, before they can be implemented in an actual persuasive system. Among the widely used scales is the Susceptibility to Persuasive Strategies (STPS) developed by Kaptein et al. [7] to measure individuals’ susceptibility to Cialdini’s persuasive strategies. Another scale is the Persuadability Inventory (PI) developed by Busch et al. [23] to measure individuals’ susceptibility to five persuasive strategies. Using these scales, researchers can investigate the susceptibility of their potential users to various persuasive strategies before implementing them in an actual persuasive system. This explicit approach allows persuasive system designers to tailor persuasive strategies to various user types.

C. Bloom’s Taxonomy of Learning

Bloom’s taxonomy is one of the most widely used and accepted learning categorizations in the education domain. This is because it underpins the classical structure of various learning methods and evaluation. Bloom’s taxonomy is a set of three hierarchical models - Cognitive (the mental process of knowing and understanding), Affective (the experience of feeling or emotion) and Psychomotor (the relationship between cognitive function and physical movement – which describes different kinds of learning behaviors and characteristics that students are expected to develop as learning progresses [12]. The Cognitive captures the process of learning through a hierarchy of categories. These categories are used to identify different stages of learning development and hence serves as a tool for structuring learning objectives in curriculums, assessments, and activities.

Cognitive ability is the ability of an individual to perform various mental activities that are most closely associated with learning. Empirical research has shown that cognitive ability moderates learning [24]. Imparting new knowledge or skills on people is synonymous to influencing people’s behavior or attitude. We discuss cognitive ability with respect to six intelligence dimensions described by Bloom [14].

Bloom identified six-dimensions that collectively determine an individual’s Cognitive ability which include: *Remembering, Understanding, Applying, Analyzing, Evaluating* and *Creating*:

1) Remembering

Remembering describes a learner’s ability to recall knowledge from memory without necessarily understanding what they mean [6]. For instance, reciting facts or list of previously learned information such as terminologies, dates, events, classifications, or persons. Examples of mental actions that relates to this function are naming, repeating, stating, and outlining. According to Ekstrom et al. [25], the *Associative Memory, Memory Span or Visual Memory Test* are the recommended psychometric test to measure a learner’s ability to remember.

2) Understanding

This represents a learner’s ability to translate ideas into other terms based on understanding [6]. For instance, a student translating an equation and implementing it as a computer program shows an understanding of the equation. To demonstrate understanding of facts and ideas, learners must be able to organize, translate, interpret and state main ideas. According to Ekstrom et al [25], the *Verbal Reasoning Test* is the recommended psychometric test to measure a learner's ability to understand.

3) Applying

This represents a learner's ability to use acquired knowledge to solve problems in new situations [14]. For instance, converting theoretical concepts learned to novel situations. Mental action words related to this function includes developing, restructuring, demonstrating, implementing, solving, employing. According to Ekstrom et al [25], the *Integrative Reasoning Test* is the psychometric test to measure a learner's ability to Apply.

4) Analyzing

This represents a learner's ability to distinguish or breakdown concepts into its component parts or determine how the parts interrelates [14]. For example, troubleshooting a piece of equipment by using logical deduction. Other activities related to analysis are probing, categorizing, deducing, discovering, inferring, scrutinizing, and experimenting. According to Ekstrom et al [25], the *Numerical Reasoning Test* is the recommended test to measure a learner's ability to Analyze.

5) Synthesizing

This represents a learner's ability to build a structure from diverse elements or determine how each part of a structure relates with the overall structure so that the organization is better understood [14]. Mental actions related to this function include designing, generalizing, composing, formulating, and documenting. According to Ekstrom et al [25], the *Inductive Reasoning* test should be used to measure a learner's ability to Synthesize.

6) Evaluating

This represents a learner's ability to make judgments about the value of ideas, materials, or methods within an area [14]. The ability to point out logical inconsistencies in arguments. For instance, selecting the most effective solution to a given problem is an act of evaluation. Verbs related to this ability are estimate, decide, validate, argue, and appraise. According to Ekstrom et al [25], the *Deductive Reasoning* Test is the recommended psychometric test to measure a student's ability to Evaluate.

These cognitive components might contribute to individual differences in responding to persuasive strategies. For example, a student's ability to Evaluate may underlie their scrutiny of persuasive message and making critical judgments about the persuasive message. Likewise, a student's ability to Understand may contribute to the comprehension of the content of a persuasive message.

III. METHOD

In this section, we present our research hypothesis and the demographic of our participants. We also present the instruments used to measure participants' Cognitive ability and susceptibility to persuasive strategies.

A. Research Hypothesis.

This study intends to investigate whether there is a relationship between learners' Cognitive ability and susceptibility to persuasive strategies. We hypothesize that *there is a relationship between the different Cognitive ability dimensions and susceptibility to distinct persuasive strategies*.

B. Participants

This study is based on data from 402 participants. The participants were University students from different levels and faculties. The students were distributed with respect to the courses they are studying: Computer science, mathematics, physics, biotechnology, criminology, Economics, Forestry and Wildlife management, Environmental management and Toxicology. Their ages range from 16 to over 46, with 47% aged 16-25, 23% aged 26-35, 21% aged 36-45 and 9% aged over45. Table I show the summary of participants' demographic information.

TABLE I. DEMOGRAPHIC OF PARTICIPANTS

Total Participants = 402	
Age	16-25 (47%), 26-35 (23%), 36-45 (21%), 46+ (9%)
Gender	Male (309), Female (93)
Department	Computer Science (18%), Mathematics (12%), Physics (14%), Biotechnology (16%) Criminology (10%), Economics (9%), Forestry and Wildlife Management (10%), Environmental Management and Toxicology (11%)
Levels	Level 100(31%), level 200 (24%), Level 300 (18%), level 400(16%), Masters (11%)

C. Measurement Instrument

Most Intelligent Quotient (IQ) test does not measure all the intelligence components defined in Blooms Taxonomy which informed our study. For example, the Reynold Intellectual Assessment Scales measure three cognitive dimensions; Verbal Intelligence, Nonverbal Intelligence, and Memory [26][27]. Also, some IQ test does not measure intelligence components as categorized by Bloom [14]. Raven's Progressive Matrices (RPM) used a single test consisting of 60-items to measure intelligence [28][29][30]. Therefore, because we intend to measure all the cognitive dimensions distinctively as defined by Blooms Taxonomy, we adopted test questions from the Educational Testing Service (ETS) Kit of Referenced Test for Cognitive abilities. Each cognitive dimension was measured using a test from the ETS cognitive kit.

To elicit participants' susceptibility to persuasive strategies we used the *Persuadability-Inventory Scale* (PI) developed by Busch et al [23]. This scale was chosen because it allows a comprehensive assessment of susceptibility to the strategies examined in this study. PI has been widely validated and used by many PT researchers including, Oyibo et al [31]. As shown in Table II, 6 items for assessing the Reward strategy, 5 items for assessing the Social Learning strategy and 3 items for assessing the Trustworthiness strategy. Each item was measured using a 9-point Likert scale ranging from 1 = Strongly Disagree to 9 = Strongly Agree.

D. Procedure

The test administration followed standardized administration procedure recommended by Educational Testing Service (ETS) [25]. This is to ensure reliability and objectivity of the test result. The test consists of six tests, each test examining one of the cognitive dimensions described in section 2. The ability to Remember concepts was measured using Associative Memory Test, the ability to Understand concepts was measured using Verbal Comprehension Test, the ability to Analyze concepts was measured using Integrative Processing Test, the ability to Apply was measured using Integrative Processing, the ability to Analyze was measured using Numerical Reasoning, the ability to Synthesize concepts was measured using Inductive reasoning Tests and the ability to Evaluate concepts was measured using Deductive Reasoning Test. The detail of the test is as shown in the Appendix, a description of the kind of task performed and the cognitive ability it measures.

Participants were tested in groups (50-52 participants) and in the same condition (quiet halls, same time, and same numbers of invigilators). The test started after a short introduction of the study. To avoid copying and ensure test integrity, participants sitting together took different subtest at a time. No personal information was collected from the participants except their age, gender, course of study, and level of study. The total time for the test administration is approximately 90 minutes.

TABLE II. STUDY'S MEASUREMENT INSTRUMENTS [23].

Social Construct	Measurement Instrument's Items
Social Learning	1.) I often modify myself to other people. 2.) I ask for advice from other people, before I make a decision. 3.) I adopt my behavior quick to the model of other people. 4.) I adapt my behavior to other people around me. 5.) I take other people as role models for new behaviors.
Reward	1.) It is important to me that my actions are rewarded. 2.) It is important for me to see my success before me. 3.) I put more ambition into something, if I know I am going to be rewarded for it. 4.) I do more work, when I know that I will get something for it (something materialistic). 5.) I am willing to change myself if I get rewarded. 6.) Rewards motivate me.
Trustworthiness	1.) I think carefully about if I trust a system before I use it. 2.) I trust information better where the source is specified. 3.) It is important for me to be precisely informed about things that I need to do, before I do them.

IV. DATA ANALYSIS

In this section, we present the reliability of our study instruments and the data analysis.

A. Reliability of Measurement Instrument

The scales that measured participants' cognitive ability for various dimensions all showed satisfactory reliability (Cronbach's α > 0.90), indicating that > 90 % of the total variance in test performance reflects true variance in intelligence (cognitive ability) and only < 10 % is due to random factors. Table III shows the results. We further validated our test instrument by checking the correlation between subtests. The largest correlation is 0.14 (between Abstract Reasoning Test and Deductive Reasoning Test), which shows that the cognitive ability subtests are independent of each other. Table IV shows the results.

Similarly, we established the reliability of items that measured susceptibility to persuasive strategies by using their Cronbach's alpha (α) score. All the constructs have α value > 0.7. Table V shows these results. With regards to validity, the PI scale demonstrated acceptable validity [23][31]. Also, our data did not violate the assumptions necessary for the correlation analysis to give a valid result. The scatterplot showed linearity between our independent and dependent variables and there was no significant outlier. Our independent and dependent variables were normally distributed, the test for normality was confirmed using the Shapiro-wilk's test (all above 0.482). Finally, each pair of independent and dependent variables were homoscedastic.

After establishing the reliability of our data, we performed Pearson's Correlation analysis to measure the linear relationship between scores on each cognitive dimension test and susceptibility to persuasive strategies (two continuous variable). The IQ scores on each cognitive dimension test was converted to standard score using the linear transformation (standard score) approach [32].

$$Z_i = (X_i - M)/SD \quad (1)$$

$$IQ_i = (Z_i * 15) + 10 \quad (2)$$

Where M is the raw mean of the sample, SD is the raw standard deviation. X_i is the raw score of respondent *i* and Z_i is respondent i's z-score.

TABLE III: INTERNAL CONSISTENCY RELIABILITY FOR COGNITIVE ABILITY DIMENSIONS

Cognitive Dimension Subtest	Cronbach's Coefficient
Remembering	0.98
Understanding	0.94
Applying	0.95
Analyzing	0.94
Synthesizing	0.92
Evaluating	0.90

TABLE IV: CORRELATION BETWEEN COGNITIVE ABILITY TEST DIMENSIONS

	RM	UN	AP	AN	SY	EV
RM	1					
UN	0.02	1				
AP	0.03	0.01	1			
AN	0.01	0.02	0.02	1		
SY	0.04	0.01	0.02	0.05	1	
EV	0.03	0.01	0.02	0.07	0.14	1

RM=Remembering, UN= Understanding, AP= Applying, AN= Analyzing, SY=Synthesizing, EV= Evaluating

TABLE V: INTERNAL CONSISTENCY RELIABILITY FOR PERSUASIVE STRATEGIES

Strategies	Cronbach's α Coefficient
Reward	0.72
Social Learning	0.82
Trustworthiness	0.76

V. RESULT

A. Correlations Between Cognitive Ability Dimensions and Persuasive Strategies

The goal of this study is to investigate the relationship between Cognitive ability and participants' susceptibility to persuasive strategies. Looking at the descriptive statistics of the subtest scores in the various cognitive ability (intelligence) dimensions in Table VI, a wide range of intellectual ability can be observed. With a minimum score of 71.51 in Deductive Reasoning (Evaluating) and a maximum score of 152.47 in Verbal Reasoning (Remembering). The range of our participants' mean score and standard deviation is similar to those of participants of other intelligence test like the Wechsler Abbreviated Scale of Intelligence (WASI-II) [33][34]. More importantly, the results show significant correlations between cognitive ability dimensions and susceptibility to persuasive strategies, see Table VII.

Our findings show that the ability to Remember and Evaluate is positively correlated with susceptibility to Reward strategy: r =0. 565 and p< 0.001, Table VII. This means that these variables tend to vary together, an individual with high ability to *Remember and Evaluate* is more likely to be susceptible to the Reward persuasive strategy. Similarly, the test scores for the *Evaluate* Cognitive ability is positively correlated with Reward strategy: r =0. 484 and p< 0.001, see Table VII.

Our findings also show that the ability *Apply, Analyze and Synthesize* is positively correlated with susceptibility to the Social Learning strategy: r =0. 470 and p< 0.001. This means that these variables tend to vary together, individuals with high ability to Apply, Analyze and Synthesize concepts are more likely to be susceptible to the Social Learning persuasive strategy. Similarly, the test scores for the *Analyze* Cognitive ability is positively correlated with Social Learning strategy: r =0. 507 and p< 0.001. Likewise, the test scores for the *Synthesize* Cognitive skill is positively correlated with Social Learning strategy: r =0. 446 and p< 0.001.

With regards to the Trustworthiness strategy, our findings show that the ability to Understand is positively correlated with susceptibility to the Trustworthiness strategy: r =0. 502 and p< 0.001. This means that these variables tend to vary together, the higher an individual's score on the Understand Cognitive dimension the more their susceptibility to the Reward persuasive strategy. Table VII summarizes these results.

VI. DISCUSSION

This study presents the result from investigating the relation between Cognitive ability and three persuasive strategies, namely Reward, Social Learning and Trustworthiness. To our knowledge, this study is the first to demonstrate that Cognitive ability determines people's susceptibility to persuasive strategies. Our results show that there are significant relationships between Cognitive ability dimensions and susceptibility to persuasive strategies.

TABLE VI: DESCRIPTIVE STATISTICS OF SCORES ON COGNITIVE ABILITY TEST

Cognitive Ability Dimensions	Min	Max	Mean	SD
Remembering	81.78	152.47	125.44	13.21
Understanding	92.47	141.35	115.43	14.21
Applying	75.23	150.23	100.26	15.01
Analyzing	71.57	143.25	114.19	13.35
Synthesizing	72.44	138.34	110.31	14.91
Evaluating	71.51	130.12	101.47	15.01

TABLE VII: CORRELATION RESULT

Cognitive Abilities Dimensions	Persuasive Strategies		
	Reward	**Social Learning**	**Trustworthiness**
Remembering	0.565**	0.036	0.163
Understanding	0.054	0.106	0.502**
Applying	0.164	0.470**	0.062
Analyzing	0.172	0.507**	0.055
Synthesizing	0.085	0.446**	0.042
Evaluating	0.484**	0.095	0.175

Correlations were computed between cognitive ability scores and susceptibility to persuasive strategies.
** p < 0.001 (two-tailed)

A. Rewards and Relation with Cognitive ability

Reward expectancies have motivational properties that influence the performance of any goal-directed behavior [35]. Our findings show that the ability to Remember is positively correlated with susceptibility to the Reward persuasive strategy. This means that, individuals who are high in ability to Remember concepts are more likely to be motivated to engage in learning activities and achieve desired learning outcomes using the reward persuasive strategy. This is presumable because students who are good with memorizing concepts/information tend to like quizzes. In quizzes people get rewarded as they answer questions correctly. For example, in most quizzes, students are asked to memorize items such as spellings of words, dates of events or definitions of terms and then asked to recall these items. They get excited as they recall these items and are rewarded for their efforts. This finding implies that a learner with high ability to Remember can be more motivated to learn by offering them rewards in recognition of their effort and achievements as they progress in the activity. This is in line with previous research in the area of learning and memory that shows that rewarding enhances people's ability to memorize and remembers facts [35]. An explanation of this result according to Adcock et al. [36] is that rewarding cues preceding remembering tasks activate the ventral tegmental area, nucleus accumbens (NAcc), and hippocampus areas of learners' brains and the higher the activation in these regions the higher an individual's memory performance. Using appropriate persuasive strategies that match learners' cognitive ability activates the right behavior change process, hence lead to the desired learning outcomes. This effect of reward is well captured by Madan et al. [37] statement "*high reward makes items easier to remember.*" **Therefore, we recommend that when Personalizing PET based on learners' cognitive ability, designers should employ the reward persuasive strategy to motivate learners high in ability to Remember (Memorize)**. Mechanisms that suggest some kind of incentive such as bonuses, points, badges, reward schedules that offer incentives as learners' progress in achieving the desired task can be applied to operationalize Reward and motivate desired learning outcomes [6].

Also, our results show that the ability to Evaluate is positively correlated the Reward persuasive strategy. This means that, people who score high in ability to Evaluate Cognitive dimension are more likely to be motivated to engage in learning and achieve desired learning outcomes using the reward persuasive strategy. This is probably because people who are intellectually good at criticizing and making logical judgement about things tend to want their efforts to be recognized and appreciated. For example, researchers and scientists are known to be good evaluators and like their works and contributions to knowledge to be acknowledged and recognized. This serves as a form of reward for their efforts. This implies that behavior change can be achieved in learners who have high ability to Evaluate by using some form of incentives. **Therefore, we recommend that to motivate people who are high in ability to Evaluate to learn, PET designers should employ the Reward persuasive strategy in their design.**

B. Trustworthiness and Relation with Cognitive Ability

According to the Persuasive System Design (PSD) model developed by Oinas-Kukkonen and Harjuuma [15], the Trustworthiness persuasive strategy is part of the system credibility support category, which holds that credible systems will be more persuasive than less credible systems. Specifically, the Trustworthiness persuasive strategy entails the provision of information that is truthful, fair, and unbiased in a persuasive system. Our findings show that the ability to Understand positively correlates with susceptibility to Trustworthiness persuasive strategy. One possible reason for this is that people with high ability to understand are more likely to scrutinize PETs critically with respect to their trustworthiness and credibility of the contents. However, once they have invested their time and effort to understand a concept, they are more likely trust the system. For example, psychologist found that individuals in a relationship who have the ability to invest their time and effort to understand each other tend to gain trust in one another compared to people in a relationship who lack the patience or the ability to understand one another [35]. This implies that learners who are good at Understanding concepts emphasize on the credibility of learning systems to determine whether or not to use them to achieve the desired learning objective, hence, they can be more easily persuaded using the Trustworthiness persuasive strategy. **Therefore, we recommend that, in personalizing PETs based on learners' cognitive ability, designer should employ the Trustworthiness persuasive strategy to motivate learners who are high in ability to understand.** There are many ways that PET can be designed to improve credibility and show Trustworthiness including using professionally designed learning systems/user interfaces, showing validation and endorsement by known authorities in the subject matter, showing testimonies, and record of success achieved so far.

C. Social Learning and Relation with Cognitive Abilities

Results of our study also show that the ability to Apply, Analyze and Synthesize concepts is positively correlated with susceptibility to Social Learning strategy. This means that these variables tend to increase together. That is, people who score high in ability to Apply, Analyze and Synthesize concepts are more likely to be motivated and engaged in learning activities and achieve the desired outcomes using the Social Learning persuasive strategy. A possible explanation for this is that these Cognitive skills require higher order thinking skills compared to the Remember and Understand Cognitive skills. It is not common to find an individual endowed with all these skills [38]. As a result, usually, tasks that require these three complex Cognitive skills are often carried out collectively in groups or as a teamwork, where individuals' skills complement one another. This has similarly been explained by Vijayaratnam et al. [39] who views Applying, Analyzing, and Synthesizing as higher order skills necessary for successful teamwork. This finding implies that, people who score high on any of these three cognitive skills can easily be motivated to learn from each other by providing opportunities for them to interact and share experience with one another during the learning process as a team. **Therefore, we recommend that to design PET targeting learners with high ability to Apply or Analyze or Synthesize concepts, designers should employ the Social Learning persuasive strategy in their design**. Designers can include tasks that require people to collaborate and work as part of a team which afford them the opportunity to observe, learn, and complement each other.

Therefore, when a learner type based on the cognitive ability is known, learners can be more easily persuaded using appropriate persuasive strategies to make the learning process more engaging and appealing.

VII. LIMITATION AND FUTURE WORK

This study is based on self-reported susceptibility to the persuasive strategies. Although this is still the most predominantly used approach, we acknowledge that the actual susceptibility may differ when implemented and evaluated in PETs. Therefore, in future, we plan to evaluate the susceptibility to the strategies operationalized in actual PETs.

VIII. CONCLUSION

Research has shown that cognitive ability can influence the learning process. Over the years, pedagogy has evolved to accommodate different learning styles. Teaching is increasingly becoming more student-centered. As a result, several Persuasive educational technologies (PETs) have been designed to engage learners and promote learning outcome. However, there is a need for PET to be designed to accommodate different learner types. This paper presents the results of an empirical study of 402 students that investigated how learners' Cognitive abilities relates to their susceptibility to three persuasive strategies: *Reward, Social Learning* and *Trustworthiness* that are commonly used in PET design. The results of the analyses show that there is a relationship between an individual's cognitive ability and their susceptibility to distinct persuasive strategies that are commonly used in PETs design. Individuals with high ability to Remember and Evaluate are susceptible to the Reward strategy while those with high ability to Understand are positively associated with the Trustworthiness strategy. Similarly, we uncover that individuals with high ability to Apply, Analyze or Synthesize ideas are positively associated with the Social Learning persuasive strategy. This implies that the cognitive abilities of learners could play an important role in their susceptibility to persuasion. These findings suggest that when deciding on the appropriate persuasive strategy to employ in PET design to motivate learners and promote learning, learners' Cognitive ability should be taken into consideration.

Our findings can guide PET designers on the appropriate persuasive strategy to employ to develop PET that will appeal to individual learners depending on their cognitive ability. Our work offers three main contributions to the frontiers in education and personalizing persuasive educational technology communities. First, we reinforce the need to *personalize* persuasive educational systems by revealing that learners of different cognitive abilities respond differently to distinct persuasive strategies. Second, we establish that the cognitive ability is an important characteristic for personalizing PETs and selecting appropriate persuasive strategies. Third, we compare the susceptibility of learners with different cognitive ability (to the strategies) and develop design guidelines for personalizing PETs to individuals based on their cognitive abilities.

To the best of our knowledge, this study is the first to investigate the relationship between learners' cognitive ability dimension and their susceptibility to distinct persuasive strategies. This is an essential step toward developing personalized PETs that will effectively engage learners and promote learning.

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APPENDIX: COGNITIVE ABILITY DIMENSIONS AND MEASUREMENT INSTRUMENT

Cognitive Ability Dimensions	**Measurement Instrument Test**	**Test Task**
Remember	Associative Memory	The task is to recall the appropriate first name that is associated with each last name. Participants were presented with a list of full names (first and last names), the last names were later presented in different order. (There was a total of 5 items of this kind.) Participants were presented with words-number pairs, the words were later presented in different order. The task is to recall the appropriate number that accompanied each word. (There was a total of 5 items of this kind.)
Understand	Verbal Comprehension	Participants were presented with a word followed by five words. The task is to name one of the five works that has the same meaning or nearly the same meaning to the word given. (There was a total of 10 items of this kind with increasing difficulties.
Apply	Integrative Processing	Participants were presented with a calendar and asked to select certain dates by following complex sets of directions. (There was a total of 5 items of this kind.) Participants were also presented with a matrix of letters. The task is to determine the point in the matrix that would be reached by following a complex set of direction. (There was a total of 5 items of this kind.)
Analyze	Numerical Reasoning	Participants were presented with complex tasks where they need to perform arithmetic operations. (There was a total of 10 items of this kind.)
Synthesize	Inductive Reasoning	Participants were presented with five sets of four letters each. The task is to find the rule which relates four of the sets to each other and to mark the one which does not fit the rule. (There was a total of 5 items of this kind.) Participants were also presented with five rows of small dashes separated into groups by small blank spaces. In each of the first four rows one dash is replaced by an "X". The task is to discover the rule and mark "X" on the fifth row where it is supposed to appear. (There was a total of 5 items of this kind).
Evaluate	Deductive Reasoning	Participants were presented with a statement followed by Five conclusions. The task is to select one of 5 conclusions that can be drawn from a given statement. (There was a total of 5 items of this kind). Participants were also presented with three objects followed by five diagrams; each diagram represents the interrelationship among these objects. The task is to select one of five diagrams which best illustrates the interrelationship among sets of three objects. (There was a total of 5 items of this kind).