Assessing the Relationship of Scientific Thinking, Self-regulation in Research, and Creativity in a Measurement Model

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Abstract
The present study investigated the relationship of the constructs scientific thinking, self-regulation in research, and creativity in a measurement model. The social cognitive theory and field theory explained that when individuals encounter of a problem, they regulate their actions, they also think scientifically and use strategies to generate creative solutions. The scales were administered to 1000 undergraduate and 839 graduate students who are currently having their thesis/dissertation across universities in Luzon (Philippines). The initial results showed a four-factor structure of scientific thinking composed of practical inclination, analytical interest, intellectual independence, and discourse assertiveness. On the other hand, the eight factors of self-regulation contextualized in research were confirmed. The measurement model structured scientific thinking, self-regulation in research, and creativity with their subscales as the manifest variable. The model showed significant relationships and path estimates for each manifest variable. The two other models were tested for the undergraduate and graduate students showed model invariance.

Keywords: Scientific thinking, self-regulation in research, creativity

When students create a research work, they engage in cognitive strategies that enable them to achieve successful performance. The use of cognitive strategies to complete one research manifests scientific thinking. From conceptualizing a research, synthesizing literature reviews, presenting the proposal, gathering data, and writing the report requires the process of self-regulation. Self-regulation in doing research involves the use of cognitive strategies that enables the student to monitor, evaluate, seek solutions, and organize their work. The process of going through the entire research process is similar to what scientists engage in when they want to prove their theory. A student who is in the process of completing his thesis or research can likewise manifest characteristics of scientific thinking (Rushton, Murray, & Paunonen, 1987). Scientific thinking is important in the conduct of research. Scientific thinking involves exploring the environment, constructing models as a basis for understanding it, and revising those models as new evidence is generated, like students who endeavor to make sense of their environments by processing data and constructing mental models based on these data (Kuhn, 1989). These activities engaged by scientists and students are measured as a set of traits and personality dispositions that determines whether one becomes interested in science as a career or related careers that require scientific thinking (Gorman, 2008). There is a rich literature explaining the nature of scientific thinking as traits or characteristics (i. e., Bachtold & Werner, 1972; Busse & Mansfield, 1984; Feist, 1998; Helmreich, Spence, & Pred, 1988; Van Zelst & Kerr, 1954). There is a need to study scientific thought in a psychological perspective (Feist, 2006). A psychological

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perspective in the study of scientific thought can (1) provide models to understand and further explain expertise and exemplified skills, (2) derive processes that help educators develop students with potential scientific-related careers, (3) focus on skills that further strengthen the scientific thinking for practitioners in science, and (4) integrate other psychological variables to create theories to explain it. In the present study, scientific thought is studied with self-regulation in research and creativity. Self-regulation in the conduct of research is related to scientific thought because every student in the field of science needs to demonstrate competence in research for the completion of their degree. Aside from this, there is a pressing issue that science literacy occupies a more central place in standards and curricula (Cavanagh, 2008). One way to develop science literacy is through training students in communicating research results. In the conduct of research, they need to be creative to generate viable and sound ideas. Andreasen (2006) explains that creative cognition is resulting from a self-organizing system. This self-organizing system is part of the self-regulation components (Zimmerman, 2002). There is evidence that creativity is meshed with scientific thought (Innamorato, 1998). Although in most reviews, authors tend to use scientific thought and scientific creativity interchangeably (i. e., Chung & Ro, 2004; Kind & Kind, 2007).

There is presently no exact theoretical model explaining the mechanism of scientific thought with self-regulation in the conduct of research and creativity. What is currently available in literature in the psychology of scientific thought are set of characteristics that make up its composition. In order to understand scientific thought better, other factors that coexist with it should also be studied like self-regulation in research and creativity. This coexistence is described as the occurrence of self-regulation process in research that increases scientific thinking and creativity. In the present study, the relationship of scientific thought, self-regulation in the conduct of research, and creativity was explored. Scientific thought in the present study was measured using a set of traits that include analytical interest, assertiveness, practical inclination, and assertiveness. Creativity is measured by creative characteristic, learning, motivation, and leadership. Self-regulation in the conduct of research include components on self-evaluating, organizing and transforming, goal-setting and planning, seeking information, keeping records and monitoring, environmental structuring, self-consequencing, rehearsing and memorizing, seeking assistance, and reviewing records.

Scientific Thinking

Scientific thinking is described in literature as both theory and practice. Kuhn (1989) describes the theoretical development of scientific thinking as metacognitive and strategic. This kind of thinking is beyond

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understanding theory but would require thinking about theories in a metacognitive sense. The evidence proposed is thought about, rather than merely being influenced by it. Kuhn (1989) further describes this thinking as reflected in the attainment of control over the interaction of theories and evidence in one's own thinking. The general skills that encompass scientific thinking according to Kuhn involves: "The scientist (a) is able to consciously articulate a theory that he or she accepts, (b) knows what evidence does and could support it and what evidence does or would contradict it, and (c) is able to justify why the coordination of available theories and evidence has led him or her to accept that theory and reject others purporting to account for the same phenomena" (p. 674). The characteristics of scientists in their theoretical work are described in scientific epistemology. Scientific epistemology is manifested in creation of scientific knowledge, instrumentation, technical discourse, social relations, and visual displays used in scientific publications (Kirby, 2003). The theoretical beliefs of scientists would affect their evaluation and generation of evidence. The organizing influence of theoretical concepts on forms of cognition range from simple categorization to complex scientific thought (Alloy & Tabachnik, 1984; Fischhoff & Beyth-Marom, 1983; Holland et al., 1986; Murphy & Medin, 1985; Neisser, 1987). Aside from the role of the scientist on theoretical development, on the practical side, scientists need to inform, influence, and evaluate the impact of policy on issues of long-term importance to various fields such as economy, human health, national security, and the health of the ecological systems that sustain quality of life (Haseltine, 2006). The stakeholders in making decisions are encouraged to make use of scientific data to ensure proper outcome. Scientific information is carried out by communicating and disseminating their findings to the community. Peer review and publication in open journals is essential to maintaining scientific rigor and integrity and establishing a record of evidence that informs policy development (Haseltine, 2006). Lee and Roth (2008) described that scientists in practice should constitute situations where science and science learning are incorporated into "good citizenship practices."

Aside from characterizing scientific thought, it is organized in different taxonomies based on how it is studied. For example, Dunbar and Fugelsang (2005) proposed four ways of studying scientific thinking:

> (1) Ex vivo research, in which a scientist is taken out of her or his laboratory and investigated using in vitro tasks. (2) In silico research, involving computational simulation and modeling of the cognitive processes underlying scientific thinking, including a diversity of approaches and case-studies (Dasgupta, 1994; Magnani, Nersessian, & Thagard, 1999; Shrager & Langley, 1990). (3) Sub specie historiae research, focusing on detailed historical accounts of scientific and technological problem-solving (Gooding & Addis, 1993; Nersessian,

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> 1984; Tweney, 1989; Tweney, Mears, & Spitzmuller, 2005). (4) In magnetico research, using techniques like MRI to study brain patterns during problem-solving, including potentially both in vitro and in vivo research (Dunbar & Fugelsang, 2005) (p. 113).

Another classification involving scientific thinking is the being an expert and novice. Scientific thinking is a construct exhibited by expert that is defined as someone who has spent many hours training or solving problems in a domain such as geology, dance, linguistics, or auto repair (Ericsson & Lehman, 1996). Further characterizations of experts are abstract thinking skills, problem-solving strategies, storage and recall of a wide array of information, and ability to work flexibly within a knowledge domain all exemplify what it means to be an expert (Bransford et al. 2000). The scientist as an expert that generates complex cognitive tasks by analyzing underlying knowledge required by accurately interpreting concepts (Reif & Allen, 1992). These characteristics are exemplified in scientific thinking.

In the educational setting, there is a greater call to develop students with more scientific skills. This is usually accompanied by training students with research skills (Feuer, Towner, & Shavelson, 2002; McGinn & Roth, 1999; Pine & Aschbacher, 2006). An education centered on building a scientific culture promotes better research. This culture also establish practices of openness, continuous reflection, and judgment. Brown, Collins, and Duguid (1989) described this approach as cognitive-apprenticeship models where students are enculturated into the practice of laboratory sciences.

In the present study, scientific thinking is composed of a set of characteristics that includes: Practical inclination, analytical interest, intellectual independence, and assertiveness. These traits are based on Feist's framework (1998) describing the classification of scientists and non-scientists traits. He was able to show that scientists and non-scientists differ in a variety of traits where scientists are high specifically on the areas of practical inclination, analytical interest, intellectual independence, and assertiveness. These classification of trait that are highly exemplified by scientists was also supported by other studies (Amabile, 1994; Charyton & Snelbecker, 2007; James & Ellison, 1973; Sansanwal & Sharma, 1993; Wilson & Jackson, 1994).

Practical inclination. One of the many skills that are important for a scientist is to acquire is practical inclination. Sternberg (2003) defined practical inclination as an intelligent factor which consists of subfactors on verbal, quantitative, and figural:

> Practical–Verbal: Everyday reasoning. Students are presented with a set of everyday problems in the life of an adolescent and have to select the option that best solves each problem.

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Practical–Quantitative: Everyday math. Students are presented with scenarios requiring the use of math in everyday life (e.g., buying tickets for a ballgame) and have to solve math problems based on the scenarios.

Practical–Figural: Route planning. Students are presented with a map of an area (e.g., an entertainment park) and have to answer questions about navigating effectively through the area depicted by the map.

Sternberg, Castejón, Hautamäki, and Grigorenko (2001) defined practical intelligence as adaptation to, shaping of, and selection of real-world environments. People high in practical intelligence are strong in using, implementing, and applying ideas and products. Laypersons have long recognized a distinction between academic intelligence (book smarts) and practical intelligence (street smarts). This distinction is represented in everyday parlance by expressions such as "learning the ropes" and "getting your feet wet." This distinction also figures prominently in the implicit theories of intelligence held by both laypeople and researchers. Sternberg, Conway, Ketron, and Bernstein (1981) asked samples of laypeople in a supermarket, a library, and a train station, as well as samples of academic researchers who study intelligence, to provide and rate the importance of characteristics of intelligent individuals. Factor analyses of the ratings supported a distinction between academic and practical aspects of intelligence for laypeople and experts alike.

Analytical interest. According to Clough (2004) science-based analytical thinking is more essential than ever in a growing range of pursuits. The goal in analytical interest is to discover knowledge, and such thinking deals with concepts, hypotheses and theories, and abstractions. Scientific method is linear and hierarchical and aims to be independent of the thinker's personal and cultural value system so that results can be repeated by anyone. Santi and Higgins (2005) explained that geologists or hydrogeologists can gain the technical knowledge and skills they need through experience and self-education. Part of this skill is analytical interest. Analytical thinking skills can be taught through a variety of exercises that enhance the geology curriculum without adding new topics, including in-class discussion questions, homework and laboratory problems, and add-ons to mapping and semester projects.

Dunn (1982) described analytical thinkers to be linear sequential and logical. Analytic individuals capture and remember information best when it is presented in a step-by-step, methodical, sequential, little by little, leading toward an understanding of the concept or lessons presented. Analytics are usually persistent because they follow directions to complete a task and do things "sequentially." They move from the beginning of a task to the end in a series of small, focused and goal-oriented steps.

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Intellectual independence. Intellectual independence can be defined as the ability of a learner to make knowledge claims independent of the traditional authorities of the teacher and textbook (Oliver & Nichols, 2001). Intellectual independence is that singular feature that makes science uniquely science. Only when humankind became aware that knowledge could be created as a result of the examination of empirical evidence, independent of the traditional authority of gods, muses, or kings, did science come to exist. In using intellectual independence in teaching, the main point for the teacher to keep constantly in mind is that his student is an investigator, seeking by means of his own efforts to find out what is truth-not a mere imitator or verifier of the results obtained by others. The conclusions reached must be deductions from the evidence observed, not statements memorized from a text or learned from a teacher. The laws and principles derived must be inferences warranted by the conclusions from the evidence.

In describing an intellectual independent student, they should learn to trust his own powers and grow strong in the assurance of first-hand knowledge. He tests and observes for himself, and receives nothing upon mere authority. No other exercise so develops the freedom and confidence of independent thinking (Poteat, 1999). Poteat (1999) dissuaded teaching that would encourage students to accept assertions "upon mere authority."

Assertiveness. Paterson (2000) defined assertiveness as the ability to express one's needs, wants, and feelings directly and honestly and to see the needs of others as equally important. Social or generalized assertiveness is the capacity to express the real self (Lieberman, 1972) without any sense of guilt (McFall & Lillesand, 1971). It is the ability to say "no" or "yes," as appropriate, to requests-to express positive/negative feelings and conveniently initiate, sustain or terminate a social discuss (Lazarus, 1973). Difficulties with assertiveness may even represent a core vulnerability for severe psychopathology and contribute to the maintenance of social and occupational impairment.

Most cross-cultural studies of assertiveness have suggested that it is culture bound (Brown & Cross, 1991; Furnham, 1979; Garrison & Jenkins, 1986; Hall & Beil-Warner, 1978; Lineberger & Calhoun, 1983; Ness, Donnan, & Jenkins, 1983). Researchers have found differences that support the contention that there are cultural variations in the situational determinants of assertiveness (Hall & Beil-Warner; Zane, Sue, Hu, & Kwon, 1991) and in perceptions of assertive and aggressive behavior (Garrison & Jenkins, 1986). Yet, there is little research that has examined how behavioral definitions of assertiveness differ across cultural groups and the extent to which the definitions are similar. Such empirically based information could prove useful when assisting clients from different cultures to formulate assertive responses. A study by Yashioka (2000) administered a sample of 115 low-income African American, Hispanic, and Caucasian women who participated

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in 6 assertiveness role plays. A content analysis of their responses indicated that there are substantive differences in terms of what constitutes passive, assertive, and aggressive responses. On the other hand, Niikura (1999) investigated modes of self-expression as they reflect the quality of assertiveness among Japanese, Malaysian, Filipino, and U.S. white-collar workers. The author collected respondents' answers to a questionnaire consisting of 33 items involving assertiveness related to modes of expression typical of the Japanese people. Several modes of expression considered specific to the Japanese people-styles of group-oriented behavior, younger people's courtesy toward older people, and the deference of the individual to group consensus-were also found among the Malaysian and the Filipino respondents. These behaviors were in contrast to those observed among the U.S. respondents.

Self-regulation in the Conduct of Research

When scientific thinking is manifested by an expert, it is likely that they engage in complex cognitive tasks where they regulate their thoughts (Reif & Allen, 1992; Petcovic & Libarkin, 2007). According to Bandura (1986) that self-regulation constitutes sub-functions through self-reactive influence. The subprocesses involve self-observation, judgment process, and self-reaction. Zimmerman (2000) proposed self-regulation in cyclical phases: Forethought phase (task analysis, self-motivational beliefs), performance phase (self-control, self-observation), and self-reflection phase (self-judgment, self-reaction). Self-regulation is usually studied using the social cognitive theory where behavior is regulated by external outcomes, self-reflective, and self-reactive activities that enables them to exercise control over their thoughts, feeling, motivations, and actions (Bandura, 1991). Self-regulation in studies are usually used to predict successful performance whether it may be in academics, sports, health, and emotions. Self-regulation can be a domain specific factor for conducting research. The use of self-regulation in research is scarce but it is very evident in practice. For example when groups of students produce a scientific article, a significant relation was observed on sustained dialogue with telementors and careful hedging of knowledge claims (O'Neil, 2001). This sustained dialogue in producing increased knowledge claims is referred to as seeking assistance or resource use as a self-regulation activity. In this study, self-regulation occurred in the research process but it is not termed as such. The available studies on research behavior are related with self-efficacy (Maier & Curtin, 2005), interest in doing research (Bishop & Bieschke, 1998), and educational programs (Cash & Hucles, 1992). Majority of studies used social cognitive variables as factors related to students' research interests and productivity (Bieschke, Bishop, & Herbert, 1995; Bieschke, Herbert, & Bard, in press; Gelso et al., 1996; Kahn & Scott, 1997). For example, the study by Bishop and Bieschke (1998) found that

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research outcome expectations, research self-efficacy beliefs, investigative interests, artistic interests, and age were significant predictors of interest in research. On the other hand, Maier and Curtin (2005) proposed strategies for applying self-efficacy theory to research methods instruction. They found that students attending the experimental math therapy sessions showed significant improvement in fundamental math skills, overcoming a performance gap with other students in the course. The quantitative data indicates that self-efficacy theory also is a useful construct for understanding and dealing with innumeracy in the research methods classroom. Moreover, Cash and Sanchez-Hucles (1992) structured a course designed to prepare the clinical psychology student for the complex dissertation process. They found that the course significantly enhanced students' self-appraised knowledge and skills, strengthened self-efficacy expectations concerning the requisite tasks of the dissertation.

Self-regulation strategies are highly used in the conduct of research. For example, the use of self-regulation in writing a thesis manuscript involves planning or goal-setting, organizing, self-consequencing, seeking help and information, and environmental structuring (see Magno & Lajom, 2010).

Creativity

In the field of psychology, creativity can be explained with different perspectives. In the humanistic, existential, and positive psychology, creativity is associated with human nature. Creativity can also be seen as a social construct serving social purposes and reflecting the development of society (Silvia, 2007). It also reflects how people's minds have gone far (Sternberg, 2006). Chapman (1978) sees creativity as a developmental activity, nurturing personal maturity and develops identity and openness to experience. Through creativity we emphasize and heighten the qualities of experience that we meet only accidentally when confronting other things and event in the world. In terms of cognition, creativity is explained in perceptual acuity, humaness, right brain growth (still questionable), mental development, and other mental skills (Neisser, 1976; Piirto, 2004).

The field of developmental psychology also explains how creativity is developed in an individual as they mature in life. In Bronfenbrenner's ecologicoal systems theory, creativity is developed as a feeling of individuality and identity that has a favorable effect on a person's self-concept (Bronfrenbrenner, 1979; Hurlock, 1982). Studies show that the forms of creativity depend upon individual interests and abilities, opportunities to do what they want to do, and activities that give the greatest satisfaction (Eisenstadt, 1978; Goertzel, Goertzel, & Goertzel, 1978; Simonton, 1984). Some young adults find a creative outlet in hobbies while others choose vocations in which they can express their creativity. There is also evidence

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that creativity is weakened through constraints imposed by conventional socialization and challenging experiences like in the face of obstacles (Simonton, 1994).

In the 1960's from the growing demand of research, creativity came to be widely recognized as a basis for scientific achievement (Anastasi, 1980). A research conducted by MacKinnon (1962) and his associates at the University of California investigated large and significant differences in a number of personality traits between creative and non-creative groups (Welsh, 1975). Most psychologists and educators generally recognize that creative talent is not synonymous with academic intelligence and is rarely covered by tests yielding an IQ (Anastasi, 1998). Thurstone (1951) emphasized this distinction and provided a provocative analysis of the possible role of ideational fluency, inductive reasoning, and certain perceptual tendencies in creative behavior. He also called special attention to the contribution of non-intellectual, temperamental factors to creative activity. He observed that creativity is encouraged by a receptive as contrasted to a critical attitude toward novel ideas and that creative solutions are likely to occur during period of relaxed, dispersed attention that during periods of active concentration on a problem.

Guilford (1959) arrived at creativity constructs that are components of creative work. These constructs are word fluency, ideational fluency, associational fluency, expressional fluency, alternate uses, plot titles, consequences, possible jobs, making objects, sketches, match problems, and decorations. Guilford uses these constructs in developing creativity test measure although it is still in its experimental form.

According to Goleman, Kaufman, and Ray (1993) that being creative at work includes certain correctness, usefulness, valuable, meaningful, flexible, and open to new possibilities. They also considered four new myriad faces of creativity: (a) Groundbreaking ideas (ex. debt for land swaps, saving tropical forests, helping impoverished countries, theory of relativity, concept of genetic engineering), (b) Imaginative expression of caring and compassion (concept of "meals and wheels," birthing rooms, the AIDS quilt, Gandhi's strategy for protesting injustice and non-violence), (c) Grand vision of hope and truth that show the way to others (ex. Bill of rights, Gettysburg address, Martin Luther King's "I have a dream" speech, and (d) Bright ideas (includes useful and economical strategies of dealing with our practical living). These themes involve concepts of manifesting creativity with a sense of social purpose. These patterns demonstrate a purpose of improving and achieving for a larger societal benefit that will serve for other people as well. Creativity does not only manifest an individualistic concept but a societal or collective dimension as well (Markus & Kitayama, 1991; Sawyer, 2006; Weisberg, 2006).

According to Gardner (1982), being creative mean looking at an individual's specific field or domain. He refutes the concept of creativity as a global talent but rather observing an individual carrying over a specialized

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task. Observing a person's task involves how they carry over the problem and how their solution is received. And the individual has the ability to do the entire process regularly. In line with his theory of multiple intelligences, creativity is characterized by the ability to adapt to almost any situation and to make situation and to make do with whatever is at hand to reach their goals.

A contemporary view of creativity as an intelligence is explained by Sternberg (2006) in theory of successful intelligences. In this theory, creative intelligence comes out when individuals are faced with problems and they assess how well they can cope with relative novelty. In measures of intelligence, it is important to include problems that are relatively novel in nature. This theory explains creativity when individuals experience problems and how they come up with solutions considering each problem is a new task.

Abra (1997) explains that creativity can be linked with science, or any area of human endeavor is the need for motivation or impetus for self-expression. What consistently sets individuals who successfully engage in the creative process apart from those who are less successful is their dedication, commitment, steadfastness, vigor, and intensity-their motivation for creative work. Eysenck (1997) reinforces this view by proposing that creativity is a personality variable, not an ability. His research and theory added to the foundation for the study of creative problem-solving style.

Relationship of Scientific thinking, Self-regulation, and Creativity

Holmes (2004) in his book explains that across the century, famous experimentalist like Pavlov, Watson, and Tolin did not only made discoveries but their discoveries were made possible because of their creative pursuits in science. However, at the beginning of the 21st century, it has been recognized that in order to make creative pursuits workable, individuals use self-regulatory functions to monitor, evaluate, and strategically act on their behavior. This notion is recognized by some empirical evidences.

Chung and Ro (2004) in their study proposed that creativity in the classroom is developed through active employment of scientific thinking through the activity-centered decision-making process. Creativity is further developed if teaching is conducted according to the problem-solving model. They found in the study that creativity subscales on fluency, flexibility, and originality increased from pre test when scientific thinking was injected with the problem solving task. Furthermore, Innamorato (1998) explained that creativity have been considered as a substantive foundation from which scientific skills develop. The findings of Chung and Ro also support Croce on the value of aesthetics in science learning. He stated that the sciences are only tools to realize aesthetic potential. He contrasts imaginative knowledge vs. intellectual knowledge and suggests that imagination precedes thought. He claims that an artistic activity of the mind is a prerequisite to logical

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concept-forming activity: "Man is an artist long before he reasons"(Croce, in Carr, 1917, p. 35). Phenix (1964) shares a similar view that the language of science merely describes the scientists' interactions with the holistic elements: "the creations of science and of art are imaginative abstractions yielding aesthetic meanings" (p. 85).

Ivcevic and Mayer (2007) found that the scholar creative type is high on self-regulation components such as risk taking than other creative types (conventional, everyday creative, artist). They explained that this set of traits showed by the scholars make them find enjoyment and challenge in work (intrinsic motivation), are willing to take chances in the professional and financial areas (risk-taking), and are able to generate multiple ideas when presented with a problem (divergent thinking). They further explain that the predictive validity of these traits of creative scholarship is less than for the set of creativity-general traits, indicating that personality traits are most successful in predicting a fundamental decision to engage in creativity and less successful in prediction of the domain-specific nature of creativity. They also found that when people get involved in artistic or activities of intellectual creativity, they are most likely to primarily pursue one kind of work, while also having a creative life-style. This indicates that creativity is domain specific.

However, the study Shin and Zhou (2007) indicates that creativity need not be domain specific to make it work. They examined conditions under which teams' educational specialization heterogeneity was positively related to team creativity. Using a sample of 75 research and development teams, the authors theorized and found that transformational leadership and educational specialization heterogeneity interacted to affect team creativity in such a way that when transformational leadership was high, teams with greater educational specialization heterogeneity exhibited greater team creativity. In addition, teams' creative efficacy mediated this moderated relationship among educational specialization heterogeneity, transformational leadership, and team creativity.

One mechanism of self-regulation employed by creators is their willingness to take moderate risks (Sternberg & Lubart, 1995a). An individual can choose a familiar and relatively commonplace option or a more unconventional route leading to greater originality. Risk-taking is related to originality on tests of creative ability (Friedman & Foerster, 2001; Glover & Sautter, 1977), involvement and enjoyment in drawing and writing, creativity on a laboratory drawing task, and unconventionality in writing (Sternberg & Lubart, 1995b). Creativity also requires discipline, hard work, and persistence. While persistence is not significantly related to creative performance on short laboratory tasks (Sternberg & Lubart, 1995b), it predicts real life creativity that requires long periods of sustained activity, often times in face of substantial obstacles. For example, Wilson (1990) found that poets persisted in writing even in times of prolonged economic deprivation and long periods without critical acceptance for their work.

Conceptual Framework

In the present study, it is proposed that scientific thinking, self-regulation in conducting research and creativity are related. Scientific thinking is defined as a mode of exploring and coming to know the world that is within the competence of research practitioners (Kuhn, 1989). Scientific thinking makes cognitive demands that professional scientists are able to fulfill (Faust, 1984). Self-regulation in conducting research is defined as individuals' awareness of their learning processes and select useful strategies to complete a task such as conducting research (Bandura 1986; Zimmerman 1986). Self-regulation when applied to doing research includes such processes as choosing practice techniques, using memory aids, finding suitable places to work, asking relevant questions, and setting interim goals. Students become self-regulated in doing research when they monitor what they are doing, compare their progress to some internal standard, criticize or praise themselves, and have confidence in their skills. Creativity is generally defined as the production of novel and useful ideas in the research process (Amabile, Conti, Coon, Lazenby, & Heron, 1996). Creativity in the present study is defined as a set of noncognitive traits such as motivation (e.g., impulse expression, desire for novelty, risk-taking), and facilitatory personal properties like flexibility, tolerance for independence, or positive attitudes to differentness (Cropley, 2000). Ivcevic and Mayer (2007) defined a domain specific creativity such as scientific creativity which is commitment and achievement in respective domains.

The relationship among scientific thinking, self-regulation in research, and creativity is anchored in the social cognitive theory and field theories. The social cognitive theory (SCT) and field theory have a common explanation that human behavior is extensively motivated and regulated by the ongoing exercise of self-influence (Bandura, 1991; Lewin, 1936).

The SCT explain that when individuals regulate their actions, it has a strong impact on their personal agency. Social Cognitive Theory (SCT) describes learning in terms of the interrelationship between behavior, environmental factors, and personal factors. Generally, the learner acquires knowledge as his or her environment converges with personal characteristics and personal experience. Bandura explains that in the social cognitive theory, self-regulation is at the center of causal processes. Self-regulation mediates the effect of external influences to behavior. Self-regulated individuals who anticipate consequences of their actions, set goals and plan for their future, they are likely to produce desired outcomes.

On the other hand, the field theory explains that when an individual encounters a problem, one think scientifically and use strategies to generate creative solutions. The field theory is the "proposition that human behavior is

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the function of both the person and the environment. This means that one's behavior is related both to one's personal characteristics and to the social situation in which one finds oneself. When students in particular conceptualize their undergraduate thesis, they regulate most of their behavior with a purpose of performing well. The self-regulation process involves scientific thinking to accompany self-regulation for the desired goal. Hence, it is hypothesized that self-regulation in research increases scientific thinking. A student needs to come up with creative ways to regulate their actions in the research phases. Creativity serves as a mechanism how self-regulation behavior is carried out effectively. Ivcevic and Mayer (2007) explain that creativity is a result of self-regulation. They further explain that self-regulation supervises creative personality and manages their operation for desired outcomes. The function of self-regulation is to oversee and balance the process of creation and sustain conscious effort in creative activity (Strernberg & Lubart, 1995). On the other hand, creativity is also related to scientific thinking. Kind and Kind (2007) explains how they are related in two ways: (1) aspects of creativity is seen in scientific research, and (2) the approach in science is authentic in nature. The further explain that creativity in science can be contextualized in the classroom setting though creative teaching, art and science, inquiry science, and the nature of science. It is proposed that creativity increases with self-regulation and scientific thinking. These three constructs are influencing each other in order to produce a desirable result.

The social cognitive theory and Field theory also encompasses two propositions that explains the scientific thinking, self-regulation, and creativity. Winchester's thesis (1985) and Sternberg's Triarchic theory of abilities on the other hand explains the relationship between scientific thinking and creativity. Winchester's thesis (1985; 2007) rationalized the relationship among creativity and scientific skills. The thesis or proposition explains scientific creation as contiguous. This contiguity occurs as students reflect on scientific information ethically and aesthetically so that they are able to derive personal meaning from this knowledge and capsulize this knowledge into a framework of understanding. The process of deriving personal meaning of scientific information bridges the gap between scientific skills and creativity. When individuals find meaning on their work is a reflection of increased creativity. The framework of understanding is derived by the use of self-regulation processes. This also concords with Sternberg's triarchic abilities (1985) where analytic, creative, and practical abilities are related. These three aspects are automatized for the purposes of adaptation to, shaping of, and selection of environments. According to the theory of successful intelligence, creative intelligence is particularly how well an individual can cope with relative novelty. According to Sternberg (2006) that "creative people are ones who are willing and able to 'buy low and sell high' in the realm of ideas. Buying low means pursuing ideas that are unknown or

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out of favor but that have growth potential. Often, when these ideas are first presented, they encounter resistance. The creative individual persists in the face of this resistance, and eventually sells high, moving on to the next new, or unpopular idea" (p. 4). These three aspects are covered in the variables proposed in the present study. The analytic aspect is reflected in the use of self-regulation process where strategies are applied thinking on abstract and often relatively academic problems. The creative aspect of thinking involves applying the components to relatively novel and unfamiliar problems. People high in creative intelligence are strong in discovering, creating, and inventing ideas and products (Sternberg, Castejon, Prieto, Hautamaki, & Grigorenko, 2001). The practical component involves using, implementing, and applying ideas and products which are covered greatly in scientific thinking. Practical inclination is also proposed as one factors of scientific thinking which was anchored on Sternberg's theory. The link of these three aspects are further proven through confirmatory factor analysis conducted (CFA) (Sternberg, Castejon, Prieto, Hautamaki, & Grigorenko, 2001). The CFA showed that these three factors are related across two measurement models where data fits the model well.

The purpose of the present study is to assess how scientific thinking, self-regulation in research, and creativity exercise to influence each other. This is carried out by measuring these three factors with different components. To establish the relationship of these three factors in a measurement model, confirmatory factors analysis will be used. The specific research problems of the study are as follows:

1. Does scientific thought, self-regulation in conducting research, and creativity increase with each other?
2. Will the factors of scientific thought, self-regulation in conducting research, and creativity yield significant path estimates to their respective constructs?
3. Will the data fit the overall model of relating scientific thought, self-regulation in conducting research, and creativity yield significant paths to their respective factors?
4. Which sample (undergraduate students who are currently doing their research or graduate students) will the proposed model have better fit?

Method

Research Design

The design employed in the study is descriptive. In the procedure, the constructs scientific thought, self-regulation in conducting research, and creativity were intercorrelated that indicate how these constructs vary together though Confirmatory Factor Analysis (CFA). The CFA also enable to

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test whether the factors of the said constructs was significant. The procedure also allowed to test the general fit of the model for undergraduate and graduate students who are currently doing their research.

Participants

The participants were 1839 Filipino undergraduate and graduate college students from different universities in Luzon. The students were selected using purposive sampling. The inclusion criteria includes students who: (1) are currently in the proposal or data gathering phase of their thesis, (2) are working with their mentor in the study, (3) have written other research reports prior to the thesis, and (3) are majors in any courses in the social sciences (ex. psychology, behavioral science, educational psychology, science education etc.). The model is tested for both graduate and undergraduate students to determine if their characteristics fit the proposed model.

The participants were selected who belong in the universities selected in the study. There were seven universities selected in Luzon. Five universities were selected in Metro Manila, one each for Laguna, Nueva Ecija, Baguio, and Cavite. These universities were selected because (1) they offers graduate studies and have a thrust on research as indicated in their mission and vision, and (2) the size of student population in the graduate programs is sufficient for the expected number of participants.

Instruments

Scale for Scientific Thinking. The scale for scientific thinking was devised by Magno (2010) that measures characterization of a scientist. It comprises both traits and dispositions to carry out theoretical work. The scale is composed of the factors practical inclination (24 items), analytical interest (31 items), intellectual independence (35 items), and discourse assertiveness (33 items). A 4-point Lickert scale was used for each item (4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree). The items have high internal consistencies of .96, .96, .95, and .95 for practical inclination, analytical interest, intellectual independence, and discourse assertiveness respectively. Convergent valifity was also established where the four factors are all highly correlated with each other. The four factors structure was obtained using an initial principal components analysis. In another sample, the four-factor model was supported in a measurement model with all significant items with acceptable goodness of fit χ^2=28935.92, df=7374, RMS Standardized Residual=.03, RMSEA=.04. The IRT Graded Response model was used and showed appropriateness of the threshold categories for the four point scale. There is precision at 95% in the Test Information Function and all 123 items turned out to fit the Rasch model (MNSQ) values within .8 to 1.2).

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Self-regulation for Research Questionnaire (SRRQ). The SRRQ is a domain specific measure of self-regulation on conducting research. Items written for each of the 10 self-regulation components (self-evaluating, organizing and transforming, goal-setting and planning, seeking information, keeping records and monitoring, environmental structuring, self-consequencing, rehearsing and memorizing, seeking assistance, and reviewing records) based on the classification arrived at by Zimmerman and Martinez-Pons (1986). The eight factors were confirmed using CFA (N=1839). The results showed that an eight factor solution of the self-regulation in research had a good fit as indicated by χ^2=47432.81, df=8745, *RMS* Standardized Residual=.01, *RMSEA*=.01, *NFI*=.91, GFI=.95, PGI=.96. All the 112 items when used as indicators for each self-regulation in research factor had significant path loadings. The eight factors in the measurement model also had significant relationships (p<.01). Zero order correlation of the self-regulation in research factors showed to have significant relationships, p<.01. The internal consistencies of the factors also showed to be very high ranging from .89 to .97. The items were calibrated for each component based on a Graded Response Rasch Model. The analysis determined the items that required more skills to implement. Most of the items fit the Rasch Model with appropriate threshold categories.

Creativity Scale. The creativity scale measures personal creativity characteristics by Renzulli et al. (1976). The scale is based on a multiple talent approach to the identification of gifted students, these scales help identify student strengths in the areas of motivation, creativity, learning, and leadership. The factors of the scale are creative characteristics, motivational characteristics, learning characteristics, and leadership characteristics. The stability of the scale ranged from .77 to .91 where N=78, interjudge reliability was .67 to .91 where N=80. The reliability of the scale was recomputed in the present study and its factor structure was confirmed. The participants answered in a four-point scale indicating 1=Seldom or never observed this characteristic, 2=Observed this characteristic occasionally, 3=Observed this characteristic to a considerable degree, 4=Observed this characteristic almost all of the time.

Procedure

Testing personnel were trained to administer the scales to effectively carry out the instructions. The students first answer the preliminary part of the questionnaire to determine if they are qualified as participants in the study (see Participants). Standard operational procedures were implemented such as voice quality and material preparation. After the students have answered, the questionnaire and answer sheets were collected and they were debriefed about the purpose of the study.

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Descriptive statistics. The mean was used to report the levels of each measure in the scales. The standard deviation was also reported to determine the variability of the scores. All the factors of the measures were intercorrelated to establish the relationship of the factors to be entered in the Confirmatory Factor Analysis.

Confirmatory Factor Analysis (CFA). The CFA was used to assess the measurement models in the study. In the analysis, the degree to which the solution fit the data provided evidence for or against the factors of each scale in the study. In the present study, two measurements models were tested. For each measurement model, the factor scores were directly measured (manifest) and the construct being measured were the latent variable. This procedure showed whether the factors loaded significantly on the construct being measured by determining the parameter estimates. After estimating the parameters of the model, the goodness of fit of the solution to the data is evaluated. The Goodness of fit indices that will be used are RMSEA, Chi-square, Joreskog GFI/AGFI, Akaike Information Criterion, Schwarz's Bayesian Criterion, Browne-Cudeck Cross Validation Index, Bentler-Bonett, James-Mulaik-Brett Parsimonious Fit Index, and Bollen's Rho. Two common factor models were tested in the study: One for undergraduate students and another for the graduate students.

Results

The purpose of the study is to assess the relationship of scientific thinking, self-regulation in research self-regulation, creativity in a measurement model. From the overall model, two models will be further tested, one for the undergraduate and another for the graduate sample. This procedure is done by comparing which set of sample will the model fit better. The invariance of the model is tested for the graduate and undergraduate sample to by comparing fit indices of the two models.

The initial model is tested that includes all N=1839 respondents that includes undergraduate and graduate students from Luzon. This procedure is done to test whether the model fit the overall sample of the study and to assess the parameter estimates. The results for the overall model showed that scientific thinking, self-regulation in research, and creativity are significantly related to each other with path estimates .90** (between scientific thinking and self-regulation and research), .53** (between scientific thinking and creativity), and .44** (between self-regulation and creativity). All the paths for each subscale of the latent variables (scientific thinking, self-regulation in research, and creativity) are also significant (p<.001) with path estimates ranging from .30 to .64 (see Figure 1). The fit of the measurement model was found to be adequate with values χ^2=1004.20, df=101, RMS Standardized Residual=.019, RMSEA=.07, PGI=.94, Adjusted

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PGI=.92, Joreskog GFI=.94, Bentler-Bonett Normed fit Index=.98, Bentler-Bonett Non-Normed fit Index=.97, Butler Comparative Fit Index=.98, and Bollen's rho=.98. The fit indices obtained for the omnibus model showed that noncentrality estimations are low (RMS and RMSEA) and single sample goodness of fit were high (Joreskog, Bentler-Bonett). This indicates that interrelationship among scientific thinking, self-regulation in research, and creativity is a plausible explanatory model.

The data for the undergraduate students (N=1000) were isolated and the same model is tested with the same indicators and constraints. The result showed that scientific thinking, self-regulation in research, and creativity are significantly related to each other with path estimates .71** (between scientific thinking and self-regulation and research), .85** (between scientific thinking and creativity), and .72** (between self-regulation and creativity). All the paths for each subscale of the latent variables (scientific thinking, self-regulation in research, and creativity) are also significant ($p<.001$) with path estimates ranging from .20 to .38 (see Figure 2). The fit of the measurement model was found to be adequate with values χ^2=451.99, df=101, RMS Standardized Residual=.03, RMSEA=.06, PGI=.96, Adjusted PGI=.94, Joreskog GFI=.95, Bentler-Bonett Normed fit Index=.96, Bentler-Bonett Non-Normed fit Index=.96, Butler Comparative Fit Index=.97, and Bollen's rho=.96. These results indicate that interrelationship among scientific thinking, self-regulation in research, and creativity for the undergraduate sample is also a plausible explanatory model.

The same with the same indicators and constraints was tested for the graduate students (N=839). The result showed that scientific thinking, self-regulation in research, and creativity are significantly related to each other with path estimates .94** (between scientific thinking and self-regulation and research), .43** (between scientific thinking and creativity), and .28** (between self-regulation and creativity). All the paths for each subscale of the latent variables (scientific thinking, self-regulation in research, and creativity) are also significant ($p<.001$) with path estimates ranging from .22 to .83 (see Figure 3). The fit of the measurement model was found to be adequate with values χ^2=846.11, df=100, RMS Standardized Residual=.02, RMSEA=.09, PGI=.89, Adjusted PGI=.85, Joreskog GFI=.88, Bentler-Bonett Normed fit Index=.96, Bentler-Bonett Non-Normed fit Index=.96, Butler Comparative Fit Index=.96, and Bollen's rho=.97. These results indicate that interrelationship among scientific thinking, self-regulation in research, and creativity for the graduate sample is also a plausible explanatory model.

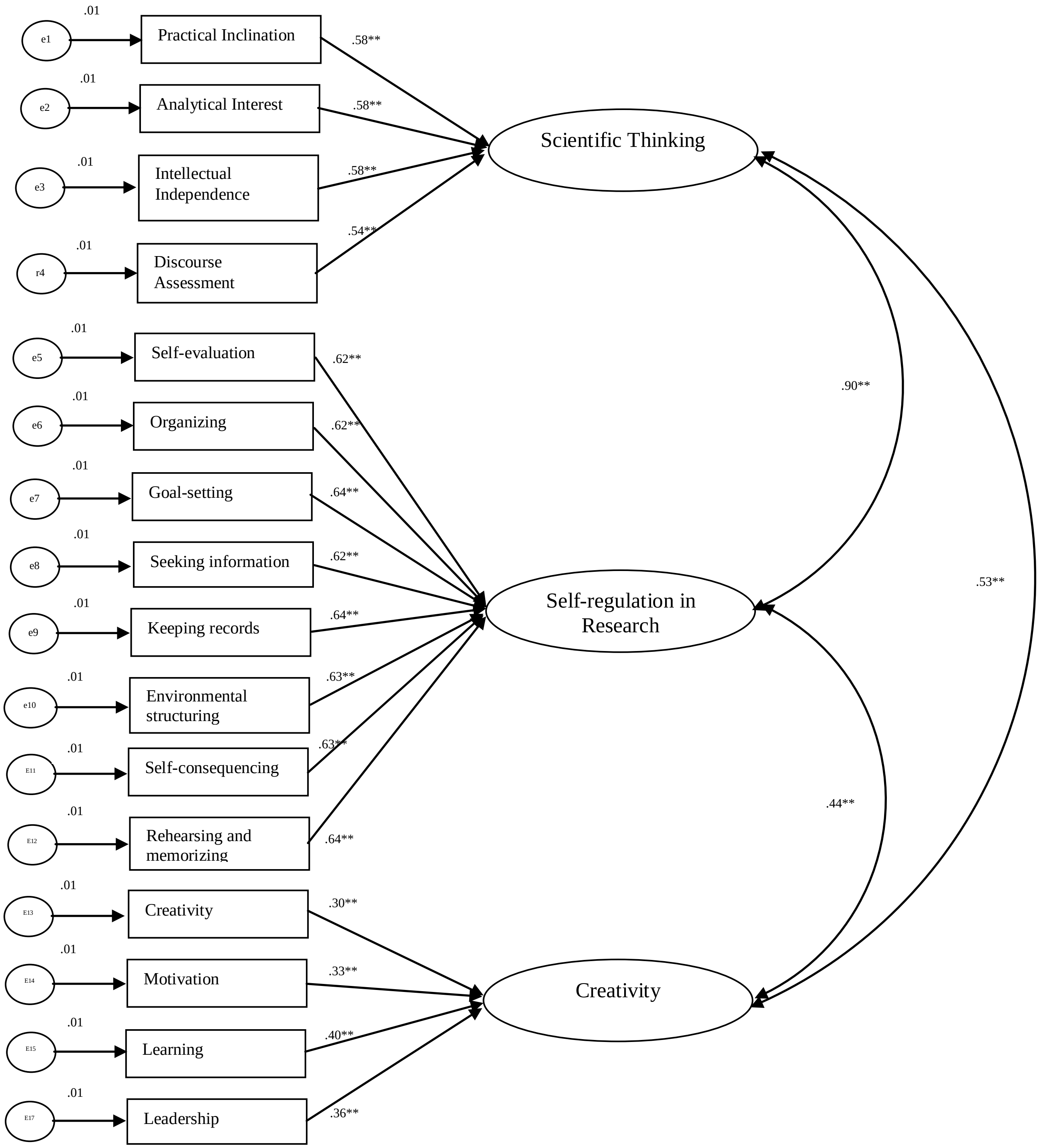

Figure 1. **Measurement Model for Scientific Thinking, Self-regulation in Research, and Creativity**

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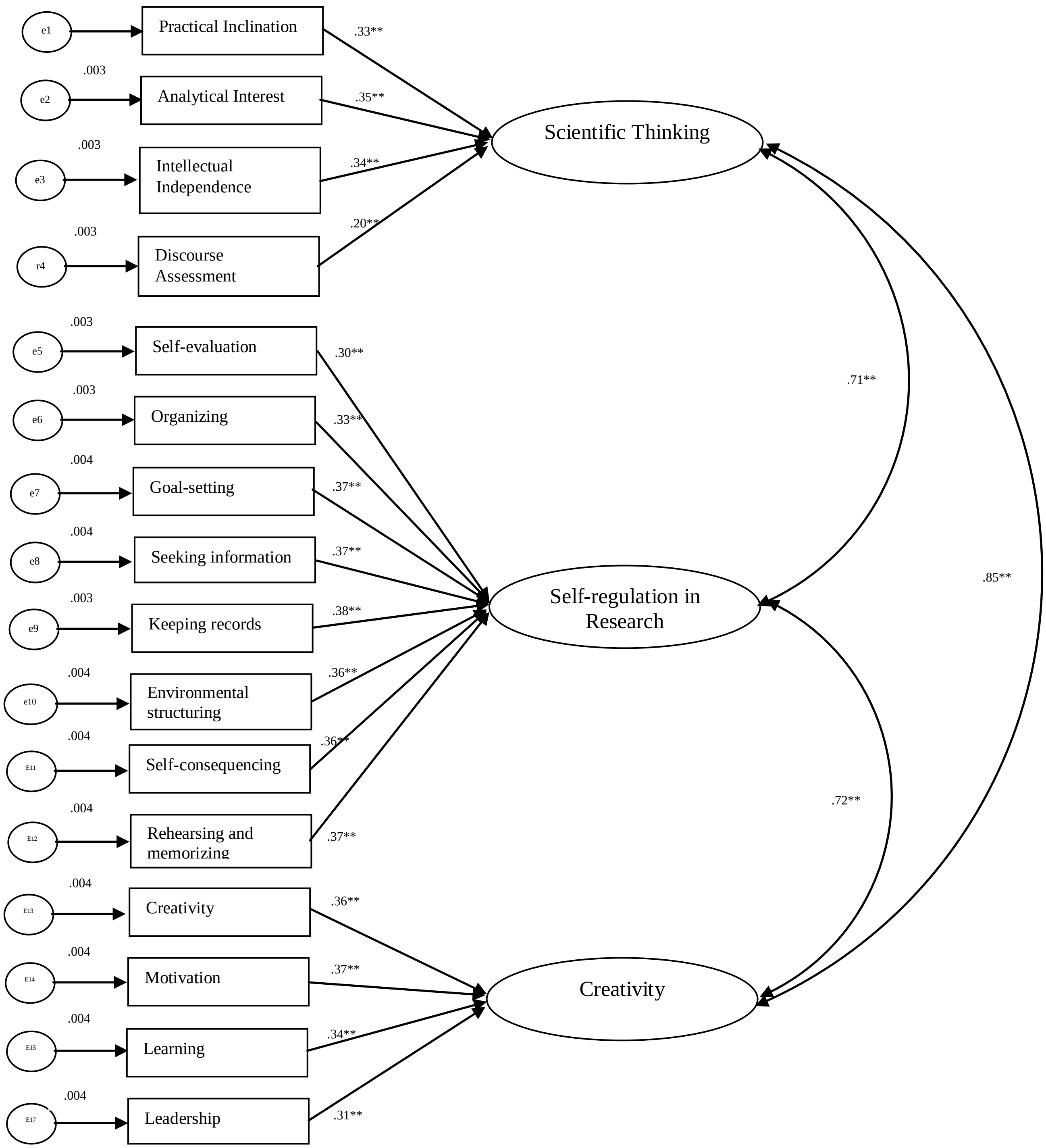

Figure 2. **Measurement Model for Scientific Thinking, Self-regulation in Research, and Creativity for Undergraduate Students**

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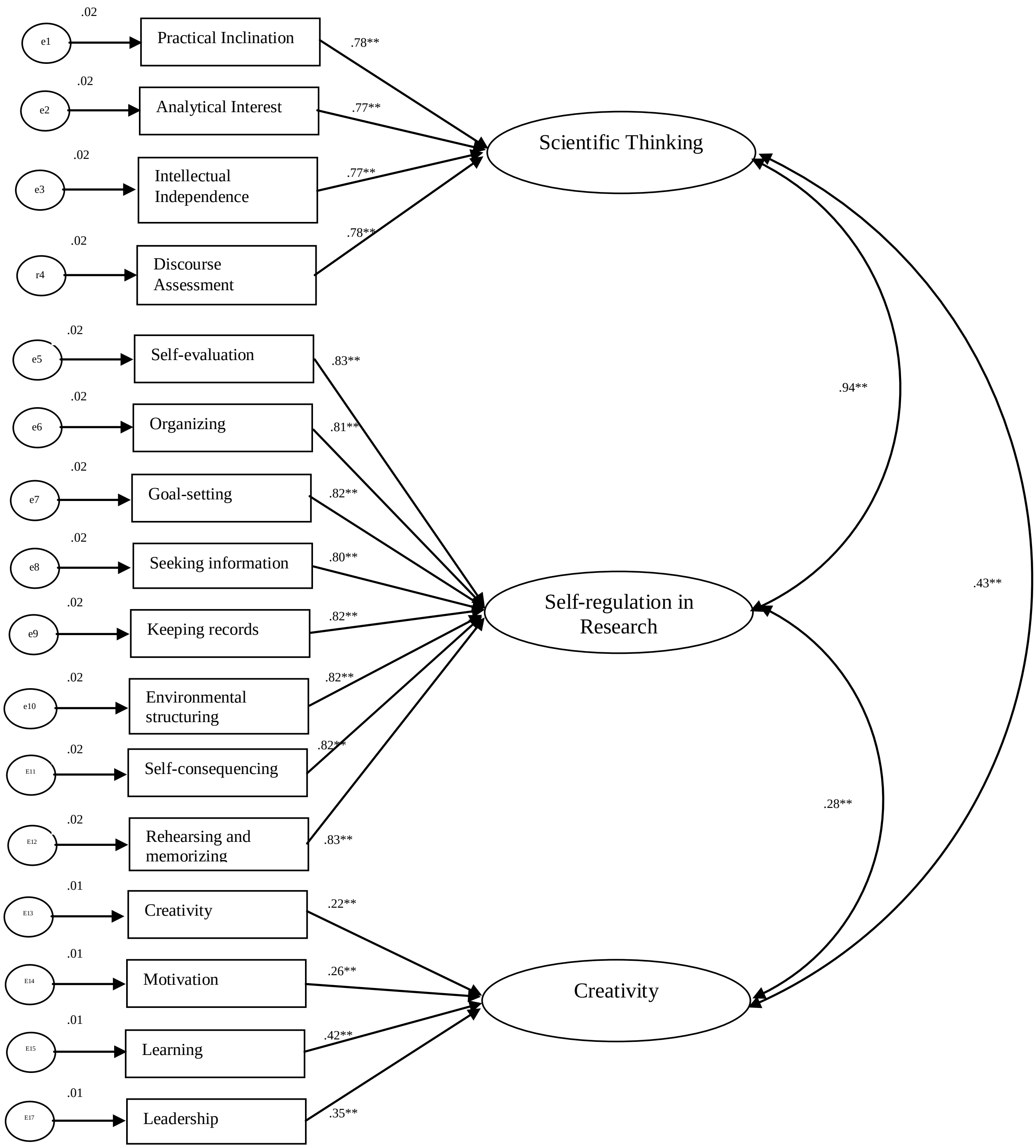

Figure 3. **Measurement Model for Scientific Thinking, Self-regulation in Research, and Creativity for Graduate Students**

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Table 1
Comparing the Fit of the Measurement Model for Undergraduate and Graduate Sample

Model	χ^2	*df*	$\Delta\chi^2$	*p*	*AIC*	*SBC*	*BCCVI*
Undergraduate	451.99	101			.52	.69	.52
Graduate	886.11	100	434.12**	.000	1.14	1.77	1.14

Note. AIC: Akaike Information Criterion, SBC: Schwartz Bayesian Criterion, BCCVI: Browne-Cudeck Cross Validation Index

In testing for the invariance of the model for the graduate and undergraduate sample, the goodness if fit indices were compared. Chi-square (χ^2) values were compared and if the probability of the difference ($\Delta\chi^2$) exceeded 95% or 99%, then the model is invariant (Byrne, 2000). In the case of the present study, the chi-square difference 434.12 that exceeding 99% probability. There is a difference between the measurement models for undergraduate and graduate samples. Other goodness of fit indices is used to test the invariance of the model. The AIC is useful primarily for deciding which of several nested models provides the best approximation to the data. When trying to decide between several models, the one with the smallest Akaike criterion is the best fitting model. The SBC is also used for deciding among several models. When deciding among several models, same like the AIC, the one with the smallest Schwarz criterion value is the best fitting model. The BCCVI requires two samples, the calibration sample for fitting the models, and the cross-validation sample. Given the obtained values for the undergraduate and graduate sample, the model consistently favors the observation for the undergraduate sample (AIC=.52, SBC=.69, BCCVI=.52). This is also consistent with the chi-square having a significantly lower value as compared with the graduate sample. This indicates that the interrelationship among scientific thinking, self-regulation in research, and creativity fits better for the undergraduate sample.

Differences in the parameter estimates between the three latent variables (scientific thinking, self-regulation in research, and creativity) were also tested. It was found that the relationship between scientific thinking and self-regulation in research is significantly stronger for the graduate sample (p<.001). However, the relationship between creativity and scientific thinking and between creativity and self-regulation in research was significantly stronger for the undergraduate sample (p>001). When the path estimates for the specific indicators of the latent constructs were tested for significant differences, the estimates for scientific thinking and self-regulation in research was significantly higher for the graduate sample while the parameter estimates for creativity was significantly higher for the undergraduate sample on motivation and creativity.

Table 17

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Comparing Path Estimates of the Manifest Variables

Manifest Variable	Estimates for the Undergraduate sample (N=1000)	Estimates for the Graduate sample (N=839)	P value
Scientific thinking			
Practical Inclination	.33	.78	.000
Analytical Interest	.35	.77	.000
Intellectual Independence	.34	.77	.000
Discourse Assertiveness	.20	.78	.000
Self-regulation in Research			
Self-Evaluation	.30	.83	.000
Organizing	.33	.81	.000
Goal-Setting	.37	.82	.000
Seeking Information	.37	.80	.000
Keeping Records	.38	.82	.000
Environmental Structuring	.36	.82	.000
Self-Consequencing	.36	.82	.000
Rehearsing and memorizing	.37	.83	.000
Creativity			
Creativity	.36	.22	.001
Motivation	.37	.26	.009
Learning	.34	.42	.04
Leadership	.31	.35	.33

Discussion

The factors confirmed for scientific thinking and self-regulation in conducting research together with creativity were structured in a measurement model to test if they are related. It was previously hypothesized that the constructs scientific thinking, self-regulation in research, and creativity converge with each other. Their point of convergence was primarily explained in the social cognitive theory and field theory. The hypothesis was supported in the present study. The constructs scientific thinking, self-regulation in research, and creativity were significantly correlated in the measurement model. The relationship of the three constructs support the assertions made by Cropley (2000), Ivcevic and Mayer (2000), and Sternberg and Lubart (1995).

The findings indicate that there is convergence when a student thinks scientifically, uses self-regulation in the conduct of research and manifests creativity. Their relationship is stringed within a scientific research domain where students' who engage in research work requires to think scientifically in order to effectively go through the process. When students engage in the

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research process, they would need to be self-regulated to execute the specific tasks well. Engaging in a research would need one to have creative pursuits to develop scientific attitude. Given this scenario, scientific thinking, self-regulation in research, and creativity explains a dynamic scientific research pursuit. This dynamic scientific research pursuit is trifocal in nature. The triad in this case is composed of the attitude aspect which is scientific thinking, a cognition factor such as self-regulation, and creativity as a disposition factor.

The feature of the triad is explained in terms of its function and utility. The functional aspect of the triad is the convergence of the three constructs. It serves to explain the tendency of learners in their increased use of one variable and the other. A research task is a scientific pursuit by nature and it is exemplified by people who are strong in scientific thinking. In the execution part, the research focus would require the individual to control their cognition and learning to effectively produce the right outcome, thus they use self-regulation strategies. A scientific attitude strengthened by the use of self-regulation requires a creative disposition in order to make novel theories and solutions. Moreover, the function of the triad is to deliberately explain what undergoes in the scientific research pursuit by looking at how these three variables are interrelated. A research task engaged by a student would exemplify these three characteristics and his or her effectiveness in accomplishing the task can be explained in the dynamics of the three constructs.

Another feature of the triad is its utility. The triad is valuable in explaining the interplay of cognition and disposition in scientific research. The triad is important because it links three important variables that interplay when an individual engages in a scientific pursuit such as research. When an individual thinks scientifically and who are self-regulated, they reflect a more creative character as demonstrated in the measurement model tested in the study. The model did not only include a cognitive part such as the scientific thinking but also a disposition variable such as creativity. The triad is useful in a sense that it combined variables in two different domains. Moreover, the relationship of scientific thinking, self-regulation in research, and creativity contributes to the theoretical foundation of explaining how experts within the line of science and research think and process information.

The triad is useful in explaining the distinctions of the model across different levels of students such as those in the undergraduate and graduate level. Two measurement models were tested for these two groups and significant model invariance was found. The model was more representative for the undergraduate level but the relationships of the variables were stronger for the graduate level. This shows that the triad is generally manifested for the undergraduate level but stronger relationship happens for graduate students. For the case of the undergraduate model, the fit suggests that the triad is feasible in explaining their cognitions and dispositions when engaged in a scientific research pursuit. However, for the graduate students their scientific thinking is largely integrated with their self-regulation and creativity when engaged in research as compared to the undergraduate. This shows that graduate students have the ability to use multiple tasks, skills, and dispositions when faced with a task. This complexity is brought about by their developmental maturity. However, for the undergraduate students the triad is useful in explaining their cognitions.

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