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Predicting Academic Success and Creative Ability in Freshman Chemical Engineering Students: A Learning Styles Perspective*

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The purpose of the paper is to investigate the predictive validity of learning styles on academic achievement and creativity gain. For this purpose, freshman chemical engineering students from Cracow University of Technology were recruited (n = 100). An experimental research design was used in this study where 49 freshman students were enrolled in a two-day creativity training course while 51 students were enrolled in traditional Humanities course. To measure creative ability the Test of Creative Thinking-Drawing Production was used as pre- and post test. Students also completed a dynamic learning style inventory that measured learning orientation, processing information, thinking, perceiving information, physical and time learning preferences, sociological, emotional and environmental preferences of learning. Student performance was measured with grade point average (GPA) and normalized creativity gain (CG). Results show that 74% of the variance in GPA and 63% of the variance in CG can be explained by learning style predictors. Global and cluster thinking are the best positive correlated predictors in GPA while a need for authority figure and intuitive perceiving information are the best negative correlated predictors in GPA. Nonconformist and self-motivation are the best positive predictors in CG while a need for structure and sequential thinking are the best negative correlated predictors in CG. The practical implications are that engineering universities should collect learning style data on students at the outset and then help students accordingly to be more successful and creative. Highly concrete sequential learners and visual theorist who are organized and self-motivated might potentially be offered more challenging honours programs with corresponding special commendations on their projects and thesis, whereas students who are more intuitive, other-motivated would receive more structure through student study groups, frequent deadlines, shorter assignments, and clearly defined learning goals for passing examinations. Active global learners need more space for acting, demanding training objectives, and more nonconventional learning objects for exploiting their creative ability.

Keywords: academic success; creativity gain; chemical engineering; learning styles; predictive validity

1. Introduction

Chemical engineering is one of the most important sectors in competitive economy and contributes highly to the gross domestic product, to employment and value added [1]. The innovative success of chemical engineering is on the one hand based on rigorous competency-based education and training, research and development services, but on the other hand also on a high level of flexibility and customer focus [2]. We can conclude that the success of engineering is not only dependent on explicit knowledge, but—more than in science-driven sectors such as chemical engineering—also on non-explicable or tacit knowledge. Tacit knowledge embodies an individual's education, natural talent, experience and judgment [2]. Tacit knowledge is difficult to generate, and for a more in-depth understanding, it is necessary to differentiate the various dimensions of knowledge as learning outcomes. Tacit knowledge should be converted from/to explicit knowledge at spiral conversion [2], and along with creativity leads to new discovery or to a patent. Creativity and innovation play a role in most levels of engineering education, and yet they are rarely discussed explicitly in courses. Engineers typically receive instruction in scientific principles and their conceptual application, but seldom do they receive formal instruction in creative problem solving [3–5]. A lack of creativity in engineering design is noticed already by industrial leaders what presents a huge obstacle for competiveness in rapidly changed technology-oriented world [3].

Several models and methods circulate how to enhance creativity but didactic methods and teaching skills are still crucial to integrate and enhance creativity at engineering design [5]. Current engineering creativity is limited at two distinct steps: idea generation and idea analysis [5] but for technological advancement and value-added innovations is regarded as not sufficient for competitive economy [6]. Several authors suggest learning style mechanism to provide in-depth student background [7–11], which can be useful to provide appropriate

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teaching and training strategies which enhance student learning and creative ability. More than this, using of personality factors could significantly predict academic achievement [12]. Openness, Intellect, and Extraversion are the traits most closely associated with creativity and creative achievement [13].The implications for education and training institutions are significant in that institution are likely to reach only some of the students in a given course if they assume that all students learn the same way or that one teaching approach will connect with all students. Institutions that are consciously aware of their students' learning styles as well as their own are in a position to make more informed choices in course material, design, and learning processes to broaden the opportunities for effective learning in their courses [11]. A use of a variety of didactical methods and approaches has the potential to enhance the learning, performance, and creative ability for a wider range of students. A multiple-scaffold learning considering learning styles, approaches to learning and strategies to studying, and intellectual development will best enable optimization of students' potential [10]. The more thoroughly teachers understand the student differences, a large possibility exists of meeting the diverse learning needs of all in learning or training process enrolled students. Even more, while creativity is difficult to teach explicitly, creating a defined space for students to practice critical thinking, problem-solving and decision making skills clearly enhanced their abilities [5], and facilitate tacit knowledge creation and diffusion, needed for innovations and patent activity [14]. A nonverbal behaviour significantly predicts creativity in collaborative peer-scaffolding learning or training argued by [15].

In this paper, we point to importance of learning styles with focus to find a composite model of learning styles which is able to measure student studying dispositions and/or preferences at broad spectrum; we point to possibility of predicting GPA and CG with learning styles. We report on research on instrument validity, reliability, and student performance; create the path model to find significant predictors on GPA and CG; examine possible ways to resolve the differences; offer suggestions for classroom activities; and suggest avenues for future research.

2. Learning styles, academic achievement and creativity

Learning style theory asserts that students become successful academically in learning environments that match their own learning style [16] while some authors [7, 13, 17] argue that learning styles as an instructional tool might be helpful in articulation of multidimensional nature of creativity.

Learning styles can be defined as "an individual's different strengths and preferences for the ways in which they absorb and process information" [7, p.568], and are treated as components of the wider concept of personality [11]. Learning style is a generic concept that frequently includes cognitive styles, personality styles, emotional and sociological styles, sensory modes, and different typologies [18]. Several learning style models circulate, but mostly are focused on single dimension or mode of perception or personal preferences [7]. According to the comparison of different learning styles models and instruments, Hawk and Shah prepared a composite which consists of eight modalities [11]: (1) Learning orientation, (2) Information processing, (3) Understanding/Thinking, (4) Perceiving information, (5) Physical and time orientation, (6) Sociological orientation, (7) Emotionality, and (8) Environmental features.

Learning orientation and information processing is solid covered with Kolb learning style inventory (LSI), proved as valid and reliable enough instrument [19]. At dimension of thinking and perceiving information, the Myers-Briggs Type Indicator, Gregorc Style Delineator, Felder-Silverman and Dunn and Dunn LSIs are developed, and have been widely accepted in engineering education literature [7], but there is a weak support for validity and reliability of that instruments [11]. Even of this, Felder-Silverman LSI may be considered as reliable, valid, and suitable enough for surveying engineering students [9]. Beside this, a new need for detecting cluster thinkers is appeared, especially out of effective context mapping of cluster thinkers which results on higher order cognitive level concepts [20]. Cognitive processes that were mentioned are crucial in the creative process. Several authors point to interesting links between how these processes function and creativity itself [7, 13, 14, 21]. Not always do these results provoke an enthusiastic look at this activity [21, 22]. Besides cognitive factors, another important group is emotional factors and motivational ones, and the social environment that can trigger creative developments or effectively block it [5, 13]. Modalities of Physical and time, sociological, emotionality and environment are successfully covered with Dunn and Dunn inventory [23], reliability and validity is judged to be moderate.

Considering the assumptions of general theoretical and term definition comparability of the models, there are further complications in the attempt to find a universal approach. They are: (1) the scarcity of research supporting the validity and reliability of the instruments, (2) the cost of purchasing some of the instruments, (3) the use of class time to administer and interpret the instruments [11], and (4) the use of different learning methods and strategies not just experiential learning after Kolb's cycle [16].

Nevertheless, additional importance of learning styles was revealed. Some authors reported predicting validity of learning styles to forecast academic success of students [7, 12, 21, 22]. Considering academic fields or disciplines, different learning styles allow students to be successful on the field. Kolb [24] prepared very detailed classification of academic disciplines with learning styles' applied dimensions. Chemical engineering students are pragmatic, sequential learners where facts dominate. Mostly are convergent thinkers [24]. Sensing learning style of perceiving information, motivation [12], visual physical preferences [22], concrete sequential learners [17], self-effective, and responsible [21] are found to be important positive predictors in GPA [12]. Motivation to study (responsible learners) also significantly predicts GPA [12]. Concrete random (active), extraverted, other-motivated, learners with need for authority, test anxiety, and with procrastination behaviour might have negative correlation with GPA [12, 17, 21, 25].

Creative achievement as course outcome should be also predicted by several personality factors. Divergent thinking, openness to experience and intellect differently predict creative achievement in science, argued by [13, 25]. The active learners don't need a structure, but need a lot of space for acting and as global learners see the whole picture with overlapping parts [25]. A nonverbal behaviour during project-based work, or other collaborative learning significantly predict creativity [21] which is needed for tacit to tacit and tacit to explicit knowledge conversion [2]. Significant negative associations were found between abstract random learners and the creativity constructs fluency and originality [17]. Nonconformists, extraverted, and mastery goal oriented (self-motivated) learners positively contribute to CG [26], also learners with disciplined imagination, with awareness of others, and inquisitive learners [27]. Acceptance of authority and a need for structure are negatively correlated with CG argued by [25, 27].

Therefore, the objective of this paper is to investigate whether the learning styles, explored with dynamic learning style inventory as a composite learning style model, significantly predict academic success and creative ability in freshman chemical engineering students. Thus, a model of interrelationships among different modalities of learning styles, GPA and CG was proposed and tested with path analysis.

In the next sections, the methodology, which includes the course format, the sample, instrumentation, and procedure and data analysis, of this study is described. Then, the results are reported and the study is critically discussed. In the concluding section, answers to the research question are formulated.

3. Methodology

The course format, sample, instrumentation validation and specification, procedure and data analysis of our study are described in the following subsections.

3.1 Creative thinking training course

A creative thinking training is a set of exercises that are designed to unlock, expand and develop abilities of non-stereotypical and innovative approaches to problem-solving. Theoretical assumptions and results of psychological research have shown that intellectual operations involved in the creative process, are associated with categorizing, memory, and imagination. Thus, creativity training aims to develop common cognitive processes [28]. Creativity training can become a tool to work on the problem that interests us but it is also a tool for personality development and discovery of new (often locked) areas of possibilities of our cognitive and social activity.

The creative thinking training has been designed for 15 periods of instruction in a two-day course. All participants of the training were freshman chemical engineering students at Faculty of Chemical Engineering and Technology at the Cracow University of Technology. Gender distribution of students was not evenly, there were just eight male students out of 49. Students were divided into eight teams with one male student in each team. Thus, an impact of male students at course analyzing and problem-solving tasks was normalized.

The creativity training consists of three essential phases: (1) Acclimatization and team building; in the first phase it is the most important to know each other and to establish good communication (skillful listening, asking questions) between persons belonging to particular teams. It is also important to clarify mutually expectations, rules and standards that are applied to training participants. (2) Heuristic rules; in the second phase is the most important fixation (introduced in the first phase) heuristic rules that are applied during a workout and problem-solving activities. In this phase, a further collaboration in teams should be promoted. At the beginning, we point to the refraining from immediate judgment of the person or an idea. A "Provisional list of ideas murder" or phrases that inhibit the activity of creative and motivational-emotional participants is dealt. These phrases must not be used during the training. A criticism is allowed only in a constructive way. Participants have to encourage each other to generate and presenting surprising and original ideas. (3) Empowerment; Mutually peer- and/or instructor-scaffolding training to reinforce participants to cross the clichés of thought. In this phase a violation of rules could appears and it is important to warn students to be streamed with the training. Instructor must control the use of by the course design not adopted standards and rules, and control them in tolerance field. The last third phase of the training period is noticeable shift in a way how we communicate participants in teams (and between the teams). There was also a change in the quality and quantity of the solutions proposed in the exercises. In this phase of a collective mind [29] dominates trainees' sense of community and large group cohesion. A group climate gives a sense of security, and thus triggers the participants' intellectual openness, which is reflected in increased idea generation and their creative ability.

A context, exercises and suggested materials used in two-day creativity training were adopted from [30]. This manual constitutes a key set of principles and practice concerning the issues of the training. In the following subsections, creativity course's training activities of Day 1 and Day 2 are described.

3.1.1 Creativity training Day 1

Training exercises were focused on developing interpersonal skills which enhance group climate, the communication and cooperation of the students. A motivator exercise was running accordingly. The exercises in interpersonal skills were aimed for a better understanding of students who are in a team, and to increase team's cohesion by giving it a name and presentation of the totem (logo) of each team. At this stage, the students were given crayons and large sheets of paper and were asked to draw a character (totem) which will be the symbol of their team as well as come up with unusual names (Indian style) that reflect the most important characteristics. Then the whole group has presented eight works that depicted the totems of each team, and read atypical "Indian" names. The task of the whole group was to select the most original name in each team and guessing to which counterpart it belongs. The effect of work of each team was rewarded with applause. This item was repeated after each presentation made by teams of exercises to strengthen the activities and develop a sense of safety and acceptance in the group. Another exercise was to present in the form of non-verbal sculptures (created by all the members of one team). Sculpture purports represented a problem or a defined concept (often abstract). Each of the eight teams presented another problem or concept and the rest of the group was tasked guess this wordless message. The next exercise was creating a common work—drawing, which was presented in the form of simple signs, symbols referred to the current mood of individual team members. The works were presented to the groups. The teams also worked on overcoming the perception and use of the objects. For this purpose, a technique of "extraordinary application" (Unusual Uses) was used proposed by [31]. The next two exercises were the motivating group exercises. The first of them was to find as much as possible defects in products; this technique is called reverse brainstorming session. In this case, a person simulated the object and was open to criticism by peer students. The second exercise from this motivation set was aimed for improving the product, namely with the introduction of step-by-step changes at the facility. This time, the members of each team used self-selected object, which was subjected to changes. Teacher merely pointed out that this should be the subject of consumer and well known to all participants in the training. The subject should not have very complicated design or structure (e.g., a comb, a toothbrush). The results of both exercises were presented to the groups.

At Day 1 of creative thinking training, we conducted seven exercises aimed for improving communication skills, motivation and breaking locks of the participants of the each team. A work time of teams and then presentations of the achievements were significantly longer than initially expected and designed. This was due to a large number of participants in the training. Consequently, all planed exercises and workouts have not been performed and exploited entirely. However, the basic objectives of integrating teams and adopting major heuristic work rules in the training have been completed, Table 1.

3.1.2 Creativity training day 2

At Day 2 of creativity training course, the overarching objective was to develop the capacity for mental operations. Proposed training exercises were abstraction, deductive reasoning, inductive reasoning, making associations, and metaphorising. An exercise to develop abstracting was oriented to stimulation of the imagination and of activation of semantic fields while moving away from stereotypical notions associated with the analyzed object. The teams presented such definition of objects (e.g., a lamp, a window, a chair) using language puzzles. The exercise of deductive reasoning was the removing of the proposal for unusual, the output-based state of affairs. The initial assumption was, for

Table 1. Training course format

Activity day	Activity phase	Learning form	Method/technique
Day 1 (8 periods): Communication, motivation skills development and opening.	Improving communication skills	Frontal, groups of 6 students, common work. Most of the work was spatial character and resembled a form of artistic technique (collage).	Unusual names (Indian style), Totem.
	Improving motivation		Extraordinary application- typical things.
	Breaking locks	Groups of 6 students, individual, common. Non-verbal bodywork.	Non-verbal sculpturing.
Day 2 (7 periods): Developing the capacity for mental operations.	Operations of abstraction	Groups of 6 students, individual, common. Exercises to develop abstracting related to stimulate the imagination and activation of semantic fields.	Teams provide a definition of objects (e.g., a lamp, a window) using language puzzle.
	Deductive reasoning	Groups of 6 students, individual, common. The exercise of deductive reasoning consisted in removing the proposal for the unusual, the output founded state of affairs.	What would happen if the shoes come to life? Verbal explanations.
	Inductive reasoning	Groups of 6 students, individual, common. Test of analogy.	Test teams solve the analogy and the same form of analogy.
	Making associations	Groups of 6 students, individual, common. Definition of objects.	How else to define e.g., notebook. Verbal.
	Metaphorisation	Groups of 6 students, individual, common. Exercise consists of sentence completion in many different ways.	Complete the sentence. Verbal.
	Group-scaffolding.	Groups of 6 students.	Project based work.

example "What would happen if the shoes come to life" [30]. In the exercise of inductive reasoning test, teams solved the analogy with the same form of analogy. Metaphorisation exercise consisted of completing sentences in many different ways. This task was aimed, as in the case analogy, to find an accurate description which facilitates understanding of the demanding problem. The final exercise was a motivational group exercise and contained the elements of crushing, repairing and building. It was necessary to create a project of an ideal city. The teams were working simultaneously on the project of the settlement for women, men, funs of nature, and chemical sciences funs. Since the teams were eight, two teams were parallel assigned to create a project for the same group of people. To perform this exercise, different types of material were used: cardboard and paperboard boxes, colored paper, crayons, plastics pieces and artifacts, metal containers and other items of the daily use. Most of the creations were spatial character and resembled a form of artistic technique which is collage.

At Day 2, eight exercises were carried out in a total, aimed for activating and developing of the intellectual operations and for increasing the opportunities for creative and cognitive teams and individuals. A big mobilization of the whole group was noticed. The atmosphere at Day 2 has enhanced a greater freedom in offering custom solutions. Students have worked with great commitment; the joy and excitement have been evinced during inventing ideas, workout proposals, and team building. Presentations of created artifacts and mind models were original and distinctly different from each other. The aims and objectives that guided the training can be carried out as realized.

3.2 Research design and sample

We used an experimental research design to investigate whether the learning styles predict academic success and creative ability in freshman chemical engineering students. There are three key components of an experimental study design: (1) *pre- to post-test design,* (2) *treatment* and *control groups*, and (3) *assignment* of study participants. A post-test result is a measure of some attribute or characteristic that is assessed for participants in an experiment after a treatment has been provided. This design uses methods to reduce or not violate statistical assumptions such as normality and homogeneity of variance. Entire learning approach's sample and activity phases are shown in Table 2.

Variables considered in the study were: (1) Independent—Students (e.g., learning style, type of the group, sex) in groups; and (2) Dependent—Academic success measured using GPA, and normalized creativity gain (CG) as course direct outcome.

The sample of this study was drawn from freshman chemical engineering students (n = 100, 22 males, 78 females). A creativity course was performed in April 2015 where 49 students (n_m = 8, n_f = 41) were enrolled. A traditional Humanities

Table 2. Students' distribution and activity phases in EL and IBL group

Group	Day 1 (8 periods)	Day 2 (7 periods)	Number of students
Experimental	Pre-test + Creativity course + Survey	Creativity course + Post-test	49
Control	Pre-test + Humanities traditional course + Survey	Humanities traditional course + Post-test	51

course was conducted in May 2015 were 51 students (n_m = 14, n_f = 37). The venue of both courses was Cracow University of Technology, Cracow, Poland. Course duration was of two days, with fifteen learning periods in total. Students were aged 20 ± 1 years.

3.3 Instruments

As a pre- and post-test the Creative Thinking-Drawing Production (TCT-DP) [32] has been used. In this test, subjects take both versions of the test, one (A form) as pre-test and the other (B form) as post-test. Subjects complete incomplete drawings in any way they like. They may draw whatever they like and how they like: everything is permissible and everything is correct. For an assessment fourteen criteria were used defined in [32]. Maximum score on test is 72 points.

As a measure of course effectiveness, the *average normalized creativity gain* (CG) was calculated. The CG expressed with $\langle g\rangle$ in Eq. 1, is defined as the average actual gain $\langle G\rangle$ divided by the maximum possible gain [33], i.e.,

$$\langle g\rangle = \%\langle G\rangle/\%\langle G\rangle_{\max} = (\%\langle \text{post}\rangle - \%\langle \text{pre}\rangle)/(100\text{-}\%\langle \text{pre}\rangle), \quad (1)$$

where G is the actual gain and %⟨post⟩ and %⟨pre⟩ are the final (post) and initial (pre) class averages, and the angle brackets "⟨. . .⟩" indicate an average of the students taking the tests.

For surveying students' learning styles, a Dynamic Learning Style Inventory (DSLI) was used. The survey included questions on demographics, ninety five questions on eight mode predictor variables with thirty-six subscales, and self-reported grade point average (GPA) as cognitive variable. Demographic questions covered sex, age, and course level. This study has adopted self-developed instrument which has already being examined in recent studies [22]. Instrument development was involved for all eight modules and multi-language version (Slovene, English, and Polish).

For the assessment, a 6-point phrase completion scale was used as recommended [34, 35]. The new scale successfully substitutes and eliminates all limitations of the existing Likert scale. This research will be treating scale questions as being equal-interval, which will enable the investigation of the nominal properties (whether the responses are different), the ordinal properties (which response has the greater magnitude) and the interval property (the distance between two responses). The intervals of the scale together form a continuous type, from 0 (*very unlikely*) to 5 (*very likely*). It does not present the mean, but ensures the comparability of continuous responses and produces better assumptions of parametric statistics [34] while avoiding bias.

The learning orientation and processing information scales were adopted from Kolb's learning style inventory developed by [19] in four subscales with three items each. The scales of understanding/thinking and perceiving information were adopted from Felder & Silverman inventory [36]. There are four subscales with three items. A new subscale of cluster thinking was developed along Felder & Silverman scale with 3 items to measure cluster thinking to distinguish characteristics and natural abilities of student [20]. The physical and time module is organised in eleven subscales, six subscales with three items, five subscales with two items. This scale was adopted from Dunn & Dunn learning styles [23]. The sociological module is organised in three subscales with three items each. The emotionality scales was adopted from Dunn & Dunn as previous one and organised in six subscales with fourteen items in total. The environmental scale was adopted from Dunn & Dunn and it is organized in six subscales with two items and one with three items. A composite of learning styles consists of ninety-five items in total, and is ready for single module use or for holistic measurement. A new survey demonstrates DSLI features. The survey items were validated by an expert panel. Three stages were involved in the instrument development process: (1) Slight modifications such as wording changes were made to assure the suitability of items given the context of this study was within a Polish language survey settings. Original DSLI was created in Slovene version. (2) To ensure the content validity of the instrument, a content validity survey was conducted. The expert content validators were university professors (six) and applied science experts (three). Reviewers were asked to rate each item out of one-hundred eight items and determine whether the item was adequate for these specific domains on a basis of three choices: essential, useful but not essential, and neither essential nor useful. Content validity ratio (CVR) was calculated based on the ratings from these nine experts. The threshold of CVR value to maintain an item for a case of nine reviewers is 0.65 [37]. Items measuring similar concepts or with a CVR value lower than 0.65 were either removed or combined with other items. (3) The slightly revised items and combined items were sent back to the reviewers for a second-round rating to ensure they were adequate and necessary. An expert panel provided evidence of survey content validity. After item elimination and revision, there were three or two items in each subscale, ninety-five in totals. The Cronbach's coefficient alpha values, calculated based on the sample of this study, indicated the developed instrument is reliable (Table 3). In case of the multidimensionality or heterogeneousness of a test, Cronbach's alpha is not sufficient as a reliability coefficient [38]. Therefore, the test–retest reliability was calculated by comparing the scores of 63 students who filled out the test during the survey pilot study (September 2014) and again during the second study (March 2015). The intraclass correlation coefficient (ICC) was used as a measure of ipsative stability as the stability of an individual's profile over time [39].

3.4 Procedure and data analysis

Students participated in the study during real-world classroom sessions throughout a study day. Individual or group administration, testing with one version takes 15 minutes. This examination (pre-test) used first version A of TCT-DP, and after (post-test) version B. It should be noted that version B is a mirror image version of A. Applications might be used for screening (creativity training; as a selective instrument in recruitment to schools or vocations), in individual diagnosis and for research (studies of the nature, development and determinants of creativity and cross-cultural studies).

Administration of the DSLI was performed when learning/training activities of Day 1 were ended. High response rate was obtained by direct presence of teacher, instructor, and test administration. A paper and pencil survey was distributed accordingly. All (n = 100) of the enrolled students completed the survey.

Data analysis was conducted using SPSS soft-

Table 3. Reliability information and descriptives about survey subscales with a midpoint 2.5 (n = 100)

Module/dimension	Sub-dimension	Number of items	Reliability Cronbach' α	*ICC* (n = 63)	*M*	*SD*
Learning orientation	Concrete (pragmatist)	3	0.66	0.84	3.52	0.75
	Abstract (theorist)	3	0.64	0.69	3.30	0.68
Processing information	Active (impulsive)	3	0.78	0.74	2.38	0.75
	Reflective	3	0.67	0.71	2.85	0.80
Understanding/thinking	Sequential	3	0.76	0.68	3.36	0.66
	Cluster	3	0.83	0.75	3.48	0.63
	Global	3	0.77	0.70	3.55	0.76
Perceiving information	Intuitive	3	0.72	0.73	2.06	1.05
	Sensing	3	0.64	0.71	3.96	0.68
Physical and time	Visual	3	0.76	0.72	3.27	0.94
	Auditory	3	0.68	0.80	3.75	0.72
	Read/Write	3	0.70	0.68	3.68	0.78
	Tactile	3	0.81	0.83	3.42	0.89
	Kinaesthetic	3	0.84	0.66	3.88	0.67
	Requires intake	2	0.83	0.71	3.08	1.28
	Does not require intake	2	0.72	0.83	1.92	1.38
	Morning learner	2	0.64	0.75	2.10	1.32
	Afternoon learner	2	0.62	0.71	3.13	1.12
	Evening learner	2	0.83	0.61	3.40	1.30
	Needs mobility	3	0.67	0.82	3.04	1.09
Sociological	Learning alone	3	0.69	0.66	3.54	0.79
	Peer oriented	3	0.66	0.82	2.81	0.91
	Authority figures present	3	0.66	0.82	2.39	0.80
Emotionality	Self-motivated	3	0.63	0.76	3.38	0.91
	Other-motivated	3	0.70	0.76	3.88	0.63
	Persistent	3	0.64	0.87	3.66	0.81
	Responsible	2	0.66	0.74	3.23	0.86
	Nonconformist	2	0.81	0.76	1.90	1.08
	Needs structure	3	0.79	0.74	4.03	0.71
Environmental	Sound-needs quiet	2	0.85	0.81	2.87	1.54
	Sound-acceptable	2	0.85	0.79	2.06	1.52
	Light-Requires much light	2	0.64	0.81	3.66	0.95
	Light-Requires low light	2	0.71	0.79	1.78	1.43
	Needs cool environment	3	0.67	0.77	2.99	1.10
	Seating design-formal	2	0.81	0.78	3.04	1.37
	Seating design-informal	2	0.75	0.72	2.69	1.28

ware (v.22). Descriptive analyses were conducted to present the student basic information, the mean score of predictor variables (learning style subscales). We conducted a *t*-test analysis to find and confirm significant relationships within and between groups with an effect size calculated with Cohen's d.

We conducted a structural equitation modelling using AMOS software (v. 20) for joint effects of multiple interferers. To uncover the causal relations between the different DSLI dimensions, GPA, and CG, a path model was defined and tested as follows: Outcomes (GPA, CG) were hypothesized to be affected by students' learning styles, as very important aspect of student diversity [10].

4. Results

Our findings are reported as descriptive analyses of survey data, t-test analyses, and structural equation modeling analysis.

4.1 Descriptive and t-test analyses

Table 3 depicts reliability information and the average scores on the subscales. DSLI subscales are moderate to high reliable (0.62 to 0.85; respectively). Table shows that freshman chemical engineering students are still concrete sequential learners where facts dominate (pragmatist, mean (M) = 3.52, standard deviation (SD) = 0.75).

Surprisingly, a small number of reflective learners revealed that chemical engineering study programme does not enroll creative students, but convergent learning orientation (pragmatist) still dominates. In contrast to existed learning styles, DSLI introduces cluster thinker which involves approaching a decision from multiple perspectives (mental models) and reduce the handling of certainty/robustness. A cluster-thinking-style seems to prevent some obviously problematic behavior relating to knowable impaired judgment in students. Students' behavior at perceiving information is rather sensing while processing, learning, and retaining information is most effectively through movement and by listening. Students' functions best in the evening and prefer to learn alone. Students are rather motivated by others and need structure to learn and to work. They also need quiet environment with bright light, formal design of interior, and surprisingly they prefer rather a cool place.

Descriptive statistics for the pre- and post-tests of TCT-DP are shown in Table 4. The descriptive data and the comparison of measures of central tendency show that the (20 ± 1)-year-old freshman students taking Humanities traditional course scored higher on the TCT-DP post-test (mean (M) = 31.54; standard deviation (SD) = 12.23) than those who had previous creativity course exposure (M = 30.96; SD = 12.35). The results indicated a medium overall score (maximum of 72), which depicts the moderate creative ability. Further descriptive analysis indicated that the test for homogeneity of variance was nonsignificant, which meant that the sample exhibited characteristics of normality required for analysis under the assumptions of the general linear model. Levene's test for equality of variances achieved no statistical significance at pretest (F (1, 98) = 0.037, p = 0.847 > 0.05), and at post-test ($F(1, 98) = 0.07, p = 0.791 > 0.05$) . T-test revealed a significant improvement in creativity from pre- to post-test, t (99) = 3.227, p = 0.002 < 0.05. The effect size of training is regarded as medium, Cohen's d = 0.64. The *class average normalized gain* CG was 6.5% and it is regarded as low gain instructional course CG < 30% [33]. Even of thirty-four negative gains were noted. Considering only positive gained students, the *average of the single-student normalized gains* was 18% which still presents low gain course [33]. T-test of between subject effects also revealed no statistical significance between the groups, t(98) = –0.633, p = 0.528 > 0.05 and across the sex t(98) = 0.334, p = 0.739 > 0.05. All significance tests for the results were two-tailed.

4.2 Structural equation modelling analysis

A path model consists of student performance variables (GPA, CG) and variables describing students' learning styles. Many researchers argue that the most decisive and important variable influencing GPA might be visual , abstract and global thinking learner [7, 12, 17, 21, 22], while for CG, nonconformist, self-motivated visual learner should benefit at creativity gain [13, 17, 26, 27]. Until now, clear empirical evidence was still lacking. We con-

Table 4. Pre- and post-test TCT-DP descriptive statistics (n = 100)

Test	Group	Number of students	*M*	*SD*
Pretest	Treatment	49	27.34	10.73
	Control	51	29.43	10.79
	Total	100	28.41	10.76
Post-test	Treatment	49	30.96	12.35
	Control	51	31.54	12.23
	Total	100	31.26	12.23

structed a path model of effective training outcomes that are influenced by independent variables. Model fit tests were done in AMOS software, and a path model of GPA and of CG and their influencing factors with statistical significant ($p < 0.05$) standardized path coefficients is shown in Fig. 1. Exogenous entries in model were learning styles, while endogenous variables were GPA and CG. All exogenous variables effects were hypothesized to be significantly correlated with both positive and negative outcomes.

Figure 1 illustrates the path model after the attenuation correction. Outcomes are influenced by variables with significant standardized path coefficients ($p < 0.05$). According to commonly used fit indices [40, 41], we found that the fit of this model was very close. A nonsignificant *p*-value (0.90) was observed from the Chi-squared test (10.65), and the Chi square divided by its degrees of freedom was smaller than 5 (0.60). The Goodness of Fit Index, the Comparative Fit Index, and the Tucker–Lewis Coefficient values were larger than 0.95 (0.99, 1.0, and 1.16, respectively), and the root mean-squared error of approximation and the root mean square residual were smaller than 0.05 (0.00 and 0.04, respectively). The probability of close fit was larger than 0.05 (0.97). The probability level of the test of close fit was also higher than the proposed

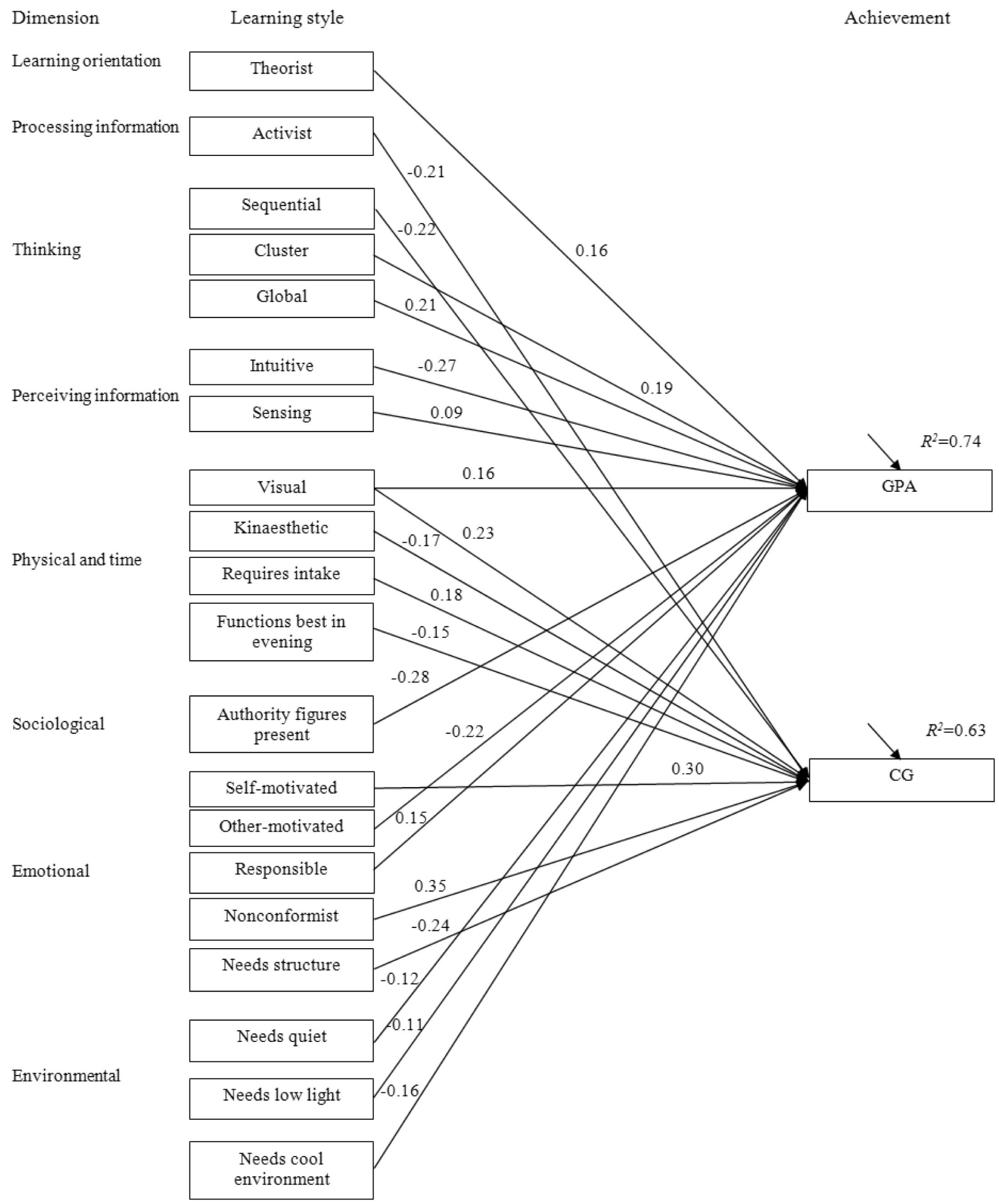

Fig. 1. Path model of GPA and of CG and their influencing factors with significant ($p < 0.05$) standardized path coefficients ($n = 100$).

threshold level of 0.50 for a good model fit [41]. This indicates a great model that does not need any improvement. All paths in the model showed significant effects.

The significant path coefficients varied from small (0.09) to strong (0.35) and the absolute rate was considered. The variance in academic achievements was explained by influencing variables in 73.4%. The most influential variables were *authority figure present* (–0.28) and *intuitive* perceiving information (–0.27) with negative correlation. A global, visual, and abstract (theorist) learner predicts most positive to GPA (0.21, 0.16, and 0.16; respectively). The variance of CG was explained for 62.4% by influencing variables of learning styles. Nonconformist and self-motivated learner contribute high to CG (0.35 and 0.30; respectively) while most negative predictor was found in a style where is a large need for structure, in sequential thinking style, and surprisingly at impulsive (activist) learner what was not expected (–0.24, –0.22, and –0.21; respectively). Eleven path coefficients had negative estimates. A high level on these learning styles scale predicts poor student achievements considering GPA and poor creative ability expressed with CG.

The explained variances were calculated using R^2 from path model where $R^2 = 0.02$ means a small impact, $R^2 = 0.13$ means a medium effect size, and $R^2 = 0.26$ presents a large effect size [42].

5. Discussion

The purpose of this study was to investigate whether the learning styles significantly predict academic success and creative ability in freshman chemical engineering students. The investigation of the students' learning styles considering multiple modalities of a composite model yielded some interesting results.

Freshman chemical engineering students are still concrete sequential learners ($M = 3.52$), oriented on facts rather than ideas. Thus, we confirmed Kolb's classification of chemical engineering students [24]. Surprisingly, we found lots of cluster thinkers, what confirms idea of Karnofsky to introduce cluster thinking style as important tool to identify those concrete learners who are able to take more risk, and are general superior for reaching good conclusions, but harder to describe and to model explicitly [20]. Those learners are very important at tacit knowledge conversion to advance creativity for innovations [2, 20, 27]. We revealed kinaesthetic preferences of students, what might lead to procrastination behaviour [21] which reduces GPA, and because of a lack of mastery goal orientation, also might reduces CG [27].

A path model revealed that global, cluster thinkers, and theorist learning style are the best positive predictors in self-reported GPA (0.21, 0.19, 0.16; respectively). Theorist learning style with sequential thinkers was expected to be decisive [25], but global learners surprisingly benefit a lot in chemical engineering study considering self-reported GPA. It points to the busy learning environment with unstructured manner of instruction, and with an intensive reflection process in the instructions or after them as students' feedback [25]. It indicates on a large share of student's reflective work, text assignments or essays included in GPA. Cluster thinkers as new introduced category seems to be rather pragmatic, motivated to study and responsible (0.15) and close to concrete sequential thinkers who are expected positively correlated to the self-reported GPA, confirmed also by [12, 17]. The most negative correlated significant predictors to GPA were a need for authority, intuitive perceiving information and other-motivated learners (–0.28, –0.27, –0.22; respectively) what confirm findings of [21, 25]. Visual learners should predict significantly positive in GPA (0.16) and in CG (0.23), and can gain benefit from multiple-nature of learning/training objects in technology-intensive learning environment [7, 22, 27]. Nonconformist behaviour (students open to experience), mastery goal orientation (self-motivated learners) are the best positive predictors in CG (0.35, 0.30; respectively), thus we confirm findings of [13, 26, 27]. Best negative correlated predictors in CG were found, namely a need for structure (-0.24) and sequential thinking style (–0.22). A lack of inquisitive behaviour and a need for structure reduce CG, confirmed by [25, 27], while sequential thinkers prefer algorithmic behaviour, especially theorist learning style [16] with abstract sequential thinkers. Surprisingly, the activist learning style significantly negative predicts in CG (–0.21). These learners need a lot of interactions and space for acting [25], and they are sociable people constantly involving themselves with others but, in doing so, they seek to centre all activities around themselves [19]. They prefer a trial and error approach (very little structure) and tend to thrive on the challenge of new experiences but are bored with implementation. The creativity course was conducted with too many concentrated groups where students were assigned with relatively not so demanding training objectives. A huge lack of space for creative acting was detected. The creativity training was organized with congested schedule, performed in two consecutive days. We point to the fact, that articulation phases of creativity training were not exploited enough. It was no time for extra practising of trial and error approach. Also, a lot of negative creativity gains were detected at active students, what point to fact that the excitement from pre-test of TCT-DP has died down and students were not motivated to do again similar template of version B, and they finished TCT-DP fast.

Another advantage of DSLI was also detected here in ability for measuring students' environmental preferences. Interesting results were revealed. The abstract sequential learners who need quiet environment [25] did not positively contribute in GPA (–0.12) and with combination of sequential learning style findings, we can point to the distraction in learning due to noise or sound. Learning objects and entire process in technology-intensive learning environment claims for more or bright light. Thus, learners who prefer low or dim light might be not so successful in learning (–0.11).

This study was conducted in light of the following two primary limitations: (1) A two-day course was too congested, physically and mentally very intensive. It caused reduction of motivation and of enlargement of procrastination behaviour at students. In spite of several creativity training models, the creativity training after articulation of Necka [30] was conducted as an elective subject matter at Cracow University of Technology. (2) A creativity course was a low gain course [33] where effectiveness of training might scarce. Students' diversity is much more recognized in medium and high gain courses, but sensitivity of measuring scales should be appropriate also at low gain courses [33].

Other limitations could consist of the quality of the program, teacher effects, and how the students perform in traditional academic courses.

6. Conclusions

This study indicated that learning styles were significant predictors of academic success and creativity gain. A composite dynamic learning style inventory was proved as reliable and valid instrument.

Our results establish a number of interesting linkages between cognitive, sociological, emotional, environmental, and psychomotor characteristics and abilities on one side and academic achievements and creativity on the other side. Taken as a whole, these findings yield a number of insights with potential practical implications on the dynamic interplay between personality and learning styles, as well as on their joint influence on academic achievement and creative ability.

Highly concrete sequential learners and visual theorist who are organized, responsible and self-motivated might potentially be offered more challenging honours programs with corresponding special commendations on their projects and thesis. Students who are more intuitive, other-motivated would receive more structure through student study groups, frequent deadlines, shorter assignments, and clearly defined learning goals for passing examinations. Active sequential learners need more structure, short group assignments, more peer or teacher scaffolding of learning or training process for improving their academic ability. Also, active (impulsive) learners need more space for acting, demanding training objectives where trial and error approach is enabled, and more nonconventional learning objects for exploiting their creative ability.

Creativity training course should be reorganized in a suggested way as three-day course, maximum of five periods a day, with small number of groups, maximum four groups for one instructor. The TCT-DP creativity test revealed some weakness, namely version A and B are similar and reduced motivation or mastery goal orientation of students. Here, we provide evidence that this frustrated most divergent and active learners who had negative gains considering post- and pre-test.

Briefly stated, we provide clear empirical evidence on how different dimensions of students' inventive ability interact. Insights into the interaction of learning styles dimensions considering cognitive, emotional, psychomotor, sociological and environmental preferences and orientation, and academic capacity and creative ability could be useful in order to design effective programmes for students in engineering education. As we concluded earlier, learning styles are found to affect academic performance and students' creative ability. Moreover, we can argue that students' emotional and sociological preferences are the most positive generator of creative gain needed for inventiveness. We found that the set up of optimal tension zone may reduce internal and external barriers which can block creative potential of students. Considering our results, learning styles show potential which to be incorporated to enhance curricula by restructuring courses, increasing hands-on activities, team dynamics, and peer scaffolding training rather than content-centred learning and training. One of the premises of the social-constructivist theory is that students actively construct their own knowledge and develop skills in interaction with other learners. Rather than simply absorbing ideas spoken at them by teachers, or somehow internalizing them through endless, repeated rote practice, constructivism posits that students actually invent their ideas. They assimilate new information to simple, pre-existing notions, and modify their understanding in light of new data. Our path model of factors affecting inventiveness reveals also a significant impact of self-motivated and non-conformist behaviour of visual learners which contributes highly to better understanding of tacit to tacit and tacit to explicit knowledge conversion. This path markedly leads to higher creative ability.

We hope these findings lead the way toward more nuanced tests of the relations among learning styles, academic success and creative ability, especially in engineering education. The practical implications are that engineering universities should collect learning style data on students at the outset and then help students accordingly to be more successful and creative. Further research is required to replicate these findings among other and larger samples, where different creativity tests and models will be exploited. Gender effects should be investigated accordingly, and we propose also introduction of aptitude test along self-reported GPA as cognitive dimension.

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