Int J Technol Des Educ (2017) 27:233–250
DOI 10.1007/s10798-015-9344-x

Predicting academic success and technological literacy in secondary education: a learning styles perspective

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Accepted: 9 November 2015 / Published online: 21 November 2015

Abstract This paper aims to investigate the predictive validity of learning styles on academic achievement and technological literacy (TL). For this purpose, secondary school students were recruited ($n = 150$). An empirical research design was followed where the TL test was used with a learning style inventory measuring learning orientation, processing information, thinking, perceiving information, physical and time learning preferences, and sociological, emotional, and environmental learning preferences. Student performance was measured with grade point average (GPA) and TL level. Results show that 69 and 65 % of the variance in GPA and TL, respectively, can be explained by learning style predictors. Responsible and visual learning styles are the best positive predictors of GPA, while a reflective learner is the best negative predictor. Self-motivated and global learners are the best positive predictors of TL, while the need for authority figures and a theorist learning orientation are the best negative predictors of TL. The practical implications are that secondary schools should collect learning style data before helping students accordingly to be successful and more technologically literate. Highly conforming, global, and visual theorists might be offered more challenging tasks and special commendations on their projects, whereas more reflective and kinaesthetic students could receive more unstructured instruction in a busy environment with learning objects that incorporate innovative experiences, personalised information, and many associations. Assimilators need more textual material, more criterion-referenced instructions to achieve higher-order thinking learning objectives, more time to complete activities or assignments, more abstract problems, and unconstrained design conditions to improve their TL.

Keywords Academic success · Technological literacy · Secondary school · Learning styles · Predictive validity

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Introduction

A rapidly changing technological society demands the greater effectiveness of education at all levels. Educational institutions make an effort to facilitate learning by introducing several new educational technologies and teaching methods of active learning, but personality factors of students are still not entirely exploited (Cox 2013; Felder and Brent 2005; Richardson et al. 2012). Students have different levels of motivation, attitudes towards teaching and learning, and different responses to learning environments and teaching methods and strategies (Felder and Brent 2005). These differences should be considered carefully, especially in secondary education (lower and upper) where a teacher-centred education prevails and students' lack of life experience is detected, thus disabling dynamic behaviour in learning (Cox 2013). Students' diversity has been shown through various factors (Felder and Brent 2005): (1) learning styles, (2) approaches to learning and studying, and (3) intellectual development. Therefore, a teacher or instructor must know their students well to facilitate learning and advance academic achievements. Learning style theory asserts that students become successful academically in learning environments that match their own learning style (Dunn 1983; Kolb 1984). Learning styles as an instructional tool should advance achievements in design and technology education (Fatt and Joo 2001), and they might also be helpful in articulating the multidimensional nature of technological literacy (TL) as the main achievement of technology education (Baker 2008; de Vries 2006). Secondary school students' TL is of great importance in encouraging the study of technology and engineering in high and post-high school education (Klapwijk and Rommes 2009). An Organization for Economic Co-operation and Development (OECD) report revealed that due to the improper selection of teaching strategies and methods, a markedly negative change in TL is detected, and an interest in the study of technology and engineering may drop after the age of 15 years (OECD 2008). Another acute problem was detected, notably that engineering universities are facing a deficit of students or/and less cognitively capable students are enrolling in technology and engineering studies (OECD 2008). In this study, we highlight the level of TL among secondary education students (lower and upper).

In Poland, where we conducted this research, secondary education has two levels: 3-year lower secondary school (*gimnazjum*), which is compulsory for all students and is referred to as stage III in the Polish education system, and several types of post-compulsory upper secondary schools, both general and vocational, referred to as stage IV and open to candidates who have successfully graduated from lower secondary schools (Eurydice 2014). In lower secondary school, the minimum number of teaching hours of technology education for the 3-year period is 130 periods with a traditional curriculum design, mostly teacher-centred, with the exception of meaningful learning as a constructivist approach. Project-, problem-, and inquiry-based learning, and other active learning approaches in technology education are rather seldom (Eurydice 2014). The technology education curriculum is not yet adjusted to the TL standards issued by ITEEA (2007). Standards for TL present content for the study of technology and engineering subject matter, where design and engineering are the most important categories (ITEEA 2007). Eurydice (2014) also reported that 48 % of lower secondary school students continue education in general upper secondary schools (*liceum ogólnokształcące*) in grades 1–3. At this level, only 30 h of teaching information technology is given as technology education. This lack of teaching may jeopardise the level of TL, which is crucial for students choosing a future career in engineering studies. Thus, engineering studies might lose the more cognitively able students that are needed from general upper secondary schools.

A lack of TL has already been observed by industrial leaders as presenting a major obstacle to competiveness in our rapidly changing, technology-oriented world (Ogot and Okudan 2006). Several models and methods explain how to enhance TL, but didactic methods and teaching skills are still crucial to integrate and enhance TL in design and engineering (Wicklein 2006). Several authors suggest a learning style mechanism to provide in-depth student background (Felder and Brent 2005; Felder and Spurlin 2005; Hawk and Shah 2007; Kappe and van der Flier 2012), which can be useful to provide appropriate teaching and training strategies that enhance student learning, problem solving, and critical thinking, and decision-making abilities. More than this, however, the use of personality factors could significantly predict academic achievement (Cox 2013; Kappe and van der Flier 2012).

The implications for education institutions are significant, as institutions are likely to recruit and relocate students to a given course or classroom for the best possible optimisation of the teaching and learning process. Institutions that are consciously aware of their students' learning styles as well as their own teaching styles are in a position to make more informed choices about course material, design, and learning processes to broaden the opportunities for effective learning in their courses (Hawk and Shah 2007). Using a variety of didactical methods and approaches has the potential to enhance the learning, performance, and TL of a wider range of students. A multiple-scaffold learning that considers learning styles, approaches to learning and strategies to studying, and intellectual development will best enable the optimisation of students' potential (Felder and Brent 2005). The more thoroughly teachers understand student differences, they more likely they are to meet the diverse learning needs of all enrolled students. Even more, while TL is difficult to teach and advance explicitly, creating a defined space for students to practise critical thinking, problem solving, and decision-making will clearly enhance their abilities (Felder 1995; Kirton 1994).

In this paper, we point to the importance of learning styles and the possibility of predicting grade point average (GPA) and TL based on learning styles. We report research on instrument validity, reliability, and student performance; create the path model to find significant ($p < 0.05$) predictors of GPA and TL; examine possible ways to resolve any differences; offer suggestions for classroom activities; and finally, propose avenues for future research.

Theoretical background

In the following subsections, the importance of learning styles in predicting GPA and TL is described.

Learning styles and academic achievement

Learning styles can be defined as an individual's different strengths and preferences for the ways in which they absorb and process information (Felder and Silverman 1988), and these are considered as components in the wider concept of personality (Hawk and Shah 2007). Learning style is a generic concept that frequently includes cognitive styles, personality styles, emotional and sociological styles, sensory modes, and different typologies (Boyd and Murphrey 2004). There exist several learning style models, mostly focused on a single dimension or mode of perception or personal preferences (Ogot and Okudan 2006). According to the comparison of different learning styles, models, and instruments, Hawk and Shah (2007) prepared a theoretical composite consisting of eight modalities: (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 are included in the Kolb learning style inventory (LSI), proved to be a valid and reliable enough instrument (Kolb and Kolb 2005). On the level of thinking and perceiving information, the Myers-Briggs Type Indicator, Gregorc Style Delineator, Felder-Silverman, and Dunn and Dunn LSIs have been developed. While these have been widely accepted in technology and engineering education literature (Ogot and Okudan 2006), there is weak support for the validity and reliability of these instruments (Hawk and Shah 2007). Nevertheless, the Felder-Silverman LSI may be considered reliable, valid, and suitable enough for surveying engineering students (Felder and Spurlin 2005). Additionally, a new need to detect cluster thinkers has appeared, especially from the effective context mapping of cluster thinkers, which results in higher-order cognitive level concepts (Karnofsky 2014). The cognitive processes mentioned are crucial in the creative process. Several authors point to the interesting links between how these processes function and creativity itself (Ogot and Okudan 2006; Kaufman et al. 2015; Richardson et al. 2012). These results do not always provoke an enthusiastic look at this activity (Avsec and Szewczyk-Zakrzewska 2015). Besides cognitive factors, other important groups are emotional and motivational factors as well as the social environment that can trigger creative developments or effectively block them (Forbes 2008; Kaufman et al. 2015). The modalities of physical and time orientation, sociological orientation, emotionality, and environment are successfully included in the Dunn and Dunn inventory (Dunn and Dunn 1989), reliability and validity is judged to be moderate.

Considering the assumptions of the general theoretical and term definition comparability of the models, there are further complications in the attempt to find a universal approach. These 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 (Hawk and Shah 2007), and (4) the use of different learning methods and strategies, not just experiential learning after Kolb's cycle (Kolb 1984).

Nevertheless, the additional importance of learning styles was reported. Some authors reported predicting the validity of learning styles to forecast the academic success of students (Avsec and Szewczyk-Zakrzewska 2015; Fazarro et al. 2009; Kappe and van der Flier 2012; Ogot and Okudan 2006; Richardson et al. 2012). Secondary school students are mostly visual, pragmatic, and sequential learners where facts dominate. Most are convergent thinkers (Felder and Silverman 1988). The sensing learning style of perceiving information, motivation (Kappe and van der Flier 2012), visual mode of presentation (Avsec and Szewczyk-Zakrzewska 2015), abstract sequential learners (Friedel and Rudd 2006), self-effective, and responsible learners (Richardson et al. 2012) are found to be important positive predictors of GPA. Study motivation (Kappe and van der Flier 2012) and some external variables (e.g., parental pressure, monetary incentives) may also contribute to the higher GPA (Fazarro et al. 2009). Random (active and reflective), extraverted, and other-motivated learners, those with a need for authority, test anxiety, and procrastination behaviour might have negative correlation with GPA (Friedel and Rudd

2006; Gregorc 2006; Kappe and van der Flier 2012; Richardson et al. 2012). Cox stated (2013) that high school freshman divergers performed at a higher level in terms of GPA, assimilators and accommodators scored very similarly, while convergers ranked lower than the three other learning style groups.

Technological literacy and different learning styles

TL is found to be a crucial achievement in technology-intensive education (de Vries 2006). It shapes the technology and engineering dimension of the educational system and defines competitive employment in a technological society (Eisenkraft 2010; Petrina 2000). TL is also defined as the individual's ability to use, manage, evaluate, assess, and understand technology (ITEEA 2007). It is determined by three complex dimensions, (1) knowledge, (2) capacity, and (3) critical thinking and decision-making (Garmire and Pearson 2006), which are interconnected and coordinated and create additional synergies. To become technologically literate, one needs factual, conceptual, procedural, and meta-cognitive knowledge to create the appropriate design of technical/technological products and/or systems (ITEEA 2007). Technologically literate individuals understand the advanced modes that change over time and evolve: what is technology, how is it created, how does it affect and change society (ITEEA 2007).

One of the important areas that must be explained across the discipline of technology education is the creation of useful instruction and instructional materials that will benefit students' attainment of TL. Using research grounded in theories of cognitive science, educators will be able to associate their knowledge with demonstrated effective teaching and learning methods. De Miranda (2004) suggests that technology education instructional methods are remarkably consistent with findings from cognitive science on the practices that define good instruction. The aims of cognitive approaches are to integrate career, skills, and academic curriculum with technology to give students the opportunity to gain TL and interact with other academic content in complement (De Miranda 2004). Information processing theory is often used to enhance TL, offering the holistic and simultaneous development of problem-solving capacities. When intrinsic and extrinsic cognitive load is high, learning produces better learning outcomes in terms of memorisation and durability of knowledge (Schunn and Silk 2011). A theory of cognitive apprenticeship is also important in technology education, as it emphasises creative educational work with a student-centred learning process and constructs their knowledge based on their own and other's experience as well as observation, imitation, and modelling, which ensures the highest level of learned tasks according to the level of cognitive processing required by each task of technology education (Schunn and Silk 2011). Distributed cognition theory is often used in complex problem solving for knowledge, critical thinking, and decision-making development. It generalises the information processing theory framework to include the physical environment around the learner, including interactions with other problem solvers (Schunn and Silk 2011). The aforementioned learning theories for technology education allow students to gain a sense of teaching practice, enhance motivational beliefs, promote self-regulation using customised strategies, draw from procedural strategies, and devote more attention and time to learning with an appropriate theoretical support (Moore et al. 2005). Such cognitive, affective, and psychological behaviours that indicate how learners perceive, interact with, and respond to the learning environment characterise several learning styles. Learning styles also tend to adopt a particular strategy in learning (Gregorc 2006). Most students have a preferred learning style, but some (all-round students) may adapt their learning styles to the task at hand (Fatt and Joo 2001).

TL has a complex structure, and, to date, clear empirical evidence on how different dimensions of TL interact and affect students' TL is still lacking. Insights into the heterogeneous structure of TL and learning styles could be useful for designing effective technology education courses or subject matter. The dimensions of TL as a technology education outcome should also be predicted by several personality factors. Technological knowledge as a dimension of TL includes factual, procedural, conceptual, and metacognitive knowledge dimensions (Garmire and Pearson 2006) on levels 1–3 of the cognitive process dimension based on revised Bloom's taxonomy (Krathwohl 2002). Sensing, verbal, and sequential students should have an advantage in learning facts (Felder and Soloman 2006) and procedures (Gregorc 2006), while global learners benefit from conceptual and metacognitive knowledge dimensions (Gregorc 2006; Pintrich 2002). One aspect of TL is focused on problem-solving ability (Avsec and Jamšek 2015; Garmire and Pearson 2006). Real problems will be better solved by concrete learners (pragmatist, activist), while non-real (abstract) problems will be better solved by abstract learners (reflector, theorist) (Aljaberi 2015; Forbes 2008; Gregorc 2006). The physical and time preferences of students markedly affect problem-solving components. Auditory, tactile, and kinaesthetic learners benefit from creativity and the support-seeking component of problem solving; tactile learners benefit from confidence, while kinaesthetic learners benefit from the avoidance component of problem solving (Gholami and Bagheri 2013). Active learners do not need a structure, but rather need lots of space for acting, while global learners see the whole picture with overlapping parts (Gregorc 2006). Markedly negative associations were found between abstract random learners, while creativity develops fluency and originality (Friedel and Rudd 2006). Conformists, extraverted, and mastery goal-oriented (self-motivated) learners are positively associated with problem-solving capacities (Kirton 1994), as are learners with a disciplined imagination, those with an awareness of others, and inquisitive learners (Houtz et al. 2003). The acceptance of authority and the need for structure are negatively correlated with problem-solving capacities as argued by Gregorc (2006) and Houtz et al. (2003). In group problem-solving work, reflective learners are disadvantaged (Felder and Spurlin 2005), while active learners are benefited, especially in real-life problems (Powell 2009). Evidence has found that visual students are successful in real-life problem solving, where multiple objects are exposed in a real-life situation (Mohamad et al. 2011). Global learners are successful in problem solving when different concepts are exploited using drawings as learning objects (Carmo et al. 2006). Accommodators and divergers (global learners) are also found to be more successful in constrained design conditions compared with other learners, namely assimilators (theorists) and convergers. In contrast, in unconstrained design conditions, divergers and assimilators are more successful than accommodators and convergers (Tezel and Casakin 2010).

Critical thinking as an important part of TL has been broadly investigated, and the impact of learning styles on critical thinking ability identified. Halpern defined critical thinking as "the use of cognitive skills or strategies that increase the probability of a desirable outcome" (1996, p. 5). Critical thinking is one of a family of closely related forms of higher-order thinking. Other forms include problem solving, creative thinking, and decision-making (Rudd et al. 2000). Critical thinking involves several constructs (Rudd et al. 2000): (1) analyticity, (2) self-confidence, (3) inquisitiveness, (4) maturity, (5) open-mindedness, (6) systematicity, (7), and truth-seeking.

Abstract sequential learners generally dominate in critical thinking, especially in inquiry-based and criterion-referenced instruction (Cox 2013), while concrete sequential, concrete random, and abstract random learners need additional attention through instructional methods and techniques to enhance their critical thinking skills (Myers and Dyer

2006). Andreou et al. (2014) reported several findings. First, active/reflective learning correlates with open-mindedness, truth seeking, analyticity, and maturity. Second, the sensitive/intuitive style positively relates to inquisitiveness. Third, low critical thinking was detected in sensing, visual, global, and reflective learners. These learners have had strong disposition to inquisitiveness, ambivalent to self-confidence and maturity, and poor to analyticity, systematicity, open-mindedness, and truth-seeking. Fourth, converging correlates with the highest level of critical thinking and diverging with the lowest. Finally, among accommodators, poor critical thinking was detected, especially in terms of analyticity, systematicity, inquisitiveness, and self-confidence, while these learners had strong dispositions to truth-seeking, maturity, and open-mindedness. They also had negative correlations for abstract conceptualising, analyticity, self-confidence, reflective observing, and truth seeking. Cox stated that "divergers are motivated to discover the relevancy or 'why' of a situation" (2013, p. 8). Diverging global learners like to reason using concrete and specific information, and to explore what a system has to offer; they prefer information to be presented in a detailed, systematic, and reasoned manner. It is said that students at the secondary school developmental stage lack the life experience (Richardson et al. 2012) that would give them an affinity to prefer another style of learning, such as the dynamics of abstract conceptualisation (Cox 2013).

Decision-making is a higher-order thinking skill associated with a behaviour that is routinely altered in response to changes occurring in the physical and social environment, meaning that outcomes involving multiple decision-makers can be hard to predict. Decisions may be altered as a result of their likely consequences (Lee 2008). According to Sofo et al. (2013), several factors affect decision-making: (1) fairness and learning; (2) context and individual capacity; (3) emotion, time pressures, and complex situations; (4) self-reflection and unconscious processing; (5) experience.

Abstract random and concrete random mind styles tend to make decisions easily, while abstract sequential learners tend to want more structure and opportunities for problem solving and research. Concrete sequential learners prefer to avoid decision-making (Chase et al. 2007). Self-motivation (mastery goal orientation) is a positive predictor of decision-making ability, while reliance on others is indicted as a negative predictor (Galotti et al. 2006). Galotti et al. (2006) argue that the information-gathering or decision-structuring phases of the process are not decisive in decision-making and suggest that stylistic measures affect the context of the decision-making process. Cluster thinkers especially make a decision from multiple perspectives, observing which decision could be implied from each perspective, and weighing the perspectives to arrive at a final decision (Karnofsky 2014). Cluster thinkers reduce a high range of perspectives into several, but not strong-weighted decisions. In some senses, cluster thinkers are capable of more robust decision-making, and thus, they can reduce complexity and time pressure, and facilitate self-reflection and unconscious processing (Karnofsky 2014).

Against this background, the objective of this paper is to investigate whether learning styles, explored through the dynamic learning style inventory as a composite learning style model, significantly predict academic success and TL in secondary school students. Thus, a model of interrelationships among different modalities of learning styles, GPA, and TL was proposed and tested with path analysis.

In the following sections, the study's method, which includes the sample, instrumentation, procedure and data analysis, is described. The results are then reported, and the study is critically discussed. In the concluding section, answers to the research question are formulated.

Methods

We used an empirical research design to investigate whether learning styles predict academic success and TL in secondary school students. The sample, instrumentation validation and specification, and procedure and data analysis of our study are described in the following subsections.

Sample

The sample of this study was drawn from lower secondary school students ($n_{ls} = 71$, 35 males, 36 females) aged 15 ± 1 years, and from upper secondary school students ($n_{us} = 79$, 44 males, 35 females) aged 18 ± 1 years. The four schools selected for this study were two lower secondary schools and two general upper secondary schools. Schools were selected on the basis of students' achievements in a national examination. The level of the selected school was regarded as average at the country level. The lower secondary schools were *Gimnazjum nr 6* and *Gimnazjum nr 22*, while the upper secondary schools were *VIII Liceum Ogólnokształcące* and *XX Liceum Ogólnokształcące*, all located in Cracow, Poland. The most important criterion in finding an appropriate sample was whether the comprehensive public secondary school offered design and technology education classes, while the upper secondary school did not offer design and technology subjects. Both groups of students were the last grade in the school. The majority ($n = 150$) of the enrolled students completed both the TL test and dynamic learning style inventory (DSLI). The participants' sex was almost evenly distributed: 52.7 % ($n_m = 79$) males and 47.3 % ($n_f = 71$) females (2 % missing values, $n = 3$).

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 self-reported GPA and level of TL.

Instruments

For surveying students' learning styles, a DSLI was used. The survey included questions on demographics, 92 questions on eight mode predictor variables with 35 subscales, and self-reported GPA as the cognitive variable. Demographic questions were related to sex, age, and education level. This study adopted a self-developed instrument that has already been examined in recent studies (Avsec and Szewczyk-Zakrzewska 2015). Instrument development was involved for all eight modules and multi-language versions (Slovene, English, and Polish).

For the assessment, a six-point phrase completion scale was used as recommended (Allen and Seaman 2007; Dawes 2008). The new scale successfully substitutes and eliminates all limitations of the existing Likert scale. This research treats scale questions as being equal-interval, which enables the investigation of nominal properties (whether the responses are different), ordinal properties (which response has the greater magnitude), and interval properties (the distance between two responses). The intervals of the scale form a continuous type, from 0 (*very unlikely*) to 5 (*very likely*). This does not present the mean, but ensures the comparability of continuous responses and produces better assumptions of parametric statistics (Dawes 2008) while avoiding bias.

The learning orientation and processing information scales were adopted from Kolb's learning style inventory developed by Kolb and Kolb (2005); the four subscales each have three items. The scales of understanding/thinking and perceiving information were based on Felder and Silverman's inventory (1988); similarly, the four subscales each have three items. A new subscale of cluster thinking was developed using the Felder and Silverman scale with three items to measure cluster thinking to distinguish the characteristics and natural abilities of students (Karnofsky 2014). The physical and time module is organised into ten subscales, comprising five subscales with three items and five subscales with two items. This scale was adopted from Dunn and Dunn learning styles (1989). The sociological module is organised into three subscales each with three items. The emotionality scale was adopted from Dunn and Dunn similar to the previous scale and organised into six subscales with fourteen items in total. The environmental scale was adopted from Dunn and Dunn and organised into six subscales with two items and one with three items. The composite of learning styles thus consists of 92 items in total for single module use or holistic measurement. A new survey demonstrates the DSLI features. The survey items were validated by an expert panel. Three stages were involved in the instrument development process. First, slight modifications such as wording changes were made to ensure the suitability of items given the context of this study within a Polish-language setting, as the original DSLI was initially created in a Slovene-language version. Second, to ensure the content validity of the instrument, a content validity survey was conducted. The expert content validators comprised six university professors and three secondary school teachers. Reviewers were asked to rate 140 items and determine whether the item was appropriate to these specific domains on a basis of three choices: essential, useful but not essential, and neither essential nor useful. The content validity ratio (CVR) was calculated based on the ratings accorded by these nine experts. According to Wilson et al. (2012), when the number of experts is nine, items with a CVR value of 0.65 or higher are considered appropriate. Items measuring similar concepts or with a CVR value lower than 0.65 were either removed or combined with other items. Third, the slightly revised and combined items were sent back to the reviewers for a second-round rating to ensure that they were adequate and necessary. An expert panel thus provided evidence of survey content validity. After item elimination and revision, three or two items remained for each subscale, with 92 items in total. The Cronbach's coefficient alpha values, calculated based on the sample of this study, indicated the reliability of the developed instrument (Table 1). In the case of multidimensionality or heterogeneousness of a test, Cronbach's alpha is not sufficient as a reliability coefficient (Rohaan et al. 2010; Rossiter 2011). Therefore, test–retest reliability was calculated by comparing the scores of 63 students who completed 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 (Rohaan et al. 2010; Weir 2005).

For measuring TL, a TL test designed by Avsec and Jamšek (2015) was used. The TL test consists of 35 items; the test was subdivided into three subscales based on the design and technology subject matter aligned with the Standards for TL issued by ITEEA (2007). Standards for TL were selected for the target group corresponding to the last grade of secondary school students (14–15-year-olds). These standards present what students should know and be able to do after design and technology subject matter lessons. Item distribution on the subscales was: (1) technological knowledge (11 items); (2) problem-solving capabilities (12 items); (3) critical thinking and decision-making (CTDM) abilities (12 items). The correct (best) answer (or combination) was scored as 1 point, while distracters were 0 points. The total score on the TL test was 35. Instrument development was involved for a multi-language version (Slovene, English, and Polish). The method for test item construction and examples was described by Avsec and Jamšek (2015).

Table 1 Reliability information and descriptives for the survey subscales with a midpoint 2.5 ($n = 150$)

Module/dimension	Sub-dimension	Number of items	Reliability Cronbach's α	*ICC* ($n = 63$)	*M*	*SD*
Learning orientation	Concrete (pragmatist)	3	0.70	0.84	3.36	0.84
	Abstract (theorist)	3	0.83	0.69	3.27	1.10
Processing information	Active (impulsive)	3	0.82	0.74	2.88	0.98
	Reflective	3	0.85	0.71	3.33	1.19
Understanding/thinking	Sequential	3	0.72	0.68	3.43	0.78
	Cluster	3	0.74	0.75	3.20	0.74
	Global	3	0.78	0.70	3.25	1.02
Perceiving information	Intuitive	3	0.71	0.73	2.76	1.06
	Sensing	3	0.72	0.71	3.59	0.89
Physical and time	Visual	3	0.66	0.72	3.22	1.03
	Auditory	3	0.65	0.80	3.38	1.03
	Tactile	3	0.79	0.83	3.15	1.04
	Kinaesthetic	3	0.86	0.66	3.53	0.89
	Requires intake	2	0.84	0.71	2.70	1.12
	Does not require intake	2	0.63	0.83	2.07	1.13
	Functions best in morning	2	0.61	0.75	2.48	1.24
	Functions best in afternoon	2	0.78	0.71	3.19	1.14
	Functions best in evening	2	0.63	0.61	2.97	1.22
	Needs mobility	3	0.68	0.82	3.07	1.08
Sociological	Learning alone	3	0.69	0.66	3.34	0.99
	Peer-oriented	3	0.72	0.82	2.58	1.17
	Authority figures present	3	0.76	0.82	2.24	1.19
Emotionality	Self-motivated	3	0.71	0.76	3.30	1.05
	Other-motivated	3	0.86	0.76	3.97	1.02
	Persistent	3	0.63	0.87	3.30	0.87
	Responsible (conforming)	2	0.80	0.74	2.91	1.15
	Nonconformist	2	0.68	0.76	1.90	1.12
	Needs structure	3	0.61	0.74	3.82	0.72
Environmental	Sound-needs quiet	2	0.75	0.81	3.04	1.46
	Sound-acceptable	2	0.74	0.79	2.20	1.19
	Light-needs much light	2	0.75	0.81	2.98	1.26
	Light-needs low light	2	0.71	0.79	2.11	1.18
	Needs cool environment	3	0.62	0.77	2.93	1.07
	Seating design-formal	2	0.69	0.78	2.70	1.14
	Seating design-informal	2	0.61	0.72	2.44	1.13

Procedure and data analysis

Data from the students were collected in April 2015 during a classroom session. Students at four schools were surveyed over a period of 2 weeks. The administration of the DSLI was first performed, taking about 15–20 min. After a short break of 5 min, the TL test was given, taking about 35–45 min. A high response rate was obtained in the presence of the teacher, instructor, and test administrator. Paper and pencil surveys were distributed accordingly. The majority ($n = 150$) of enrolled students completed both surveys.

Data analysis was performed using SPSS software (v. 22). Descriptive analyses were conducted to present the basic student information and the mean score of predictor variables (learning style subscales). We conducted an analysis of variance to identify and confirm significant ($p < 0.05$) relationships between groups with an effect size calculated with eta squared.

We performed structural equitation modelling using AMOS software (v. 20) for joint effects of multiple interferers. To determine the causal relations between the different DSLI dimensions, GPA, and TL, a path model was defined and tested as follows: outcomes (GPA and TL) were hypothesised to be affected by students' learning styles, as a very important aspect of student diversity (Felder and Brent 2005).

Results

Our findings are reported as descriptive analyses, analysis of variance, and structural equitation modeling analysis.

Descriptive analyses and analysis of variance

Table 1 depicts the reliability information and average scores on the subscales. DSLI subscales are moderately to highly reliable and stable over time (Cronbach's α 0.61–0.86, *ICC* 0.61–0.87; respectively). Table 1 shows that most individuals possess more than one preferred style of learning, but one style is often more dominant. Concrete learners prevailed ($M = 3.36$, $SD = 0.84$) followed by reflective learners ($M = 3.33$, $SD = 1.19$).

As expected, the pragmatist, theorist, and reflective students are evenly distributed, while a lack of activists is detected. Sequential thinkers prevailed, and expectedly, they use the sensing preference at perceiving information. Surprisingly, visual learners did not prevail, but there were more kinaesthetic and auditory learners. In contrast to existing learning styles, DSLI introduces cluster thinkers who approach a decision from multiple perspectives (mental models) and reduce the handling of certainty/robustness. Students function best in the afternoon and prefer to learn alone. Students are rather motivated by others and need structure to learn and work. There are more conforming and less creative students (nonconformist). They also need a quiet environment with bright light, a formal design of the interior, and, surprisingly, they prefer a cool place.

The TL test was moderately reliable in the present sample ($n = 150$), Cronbach's alpha = 0.76. Descriptive statistics for the TL test are shown in Table 2. The descriptive data and comparison of measures of central tendency show that the upper secondary school students expectedly scored higher on the TL test [mean (M) = 45.03; standard deviation (SD) = 10.74] than those from lower secondary school ($M = 34.12$; $SD = 9.17$); $p = 0.00 < 0.05$, effect size of eta squared = 0.23. Further descriptive analysis indicated that the test for homogeneity of variance was non-significant, meaning 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 in the TL test across the schooling groups [$F(1, 148) = 0.608, p = 0.437 > 0.05$] and across sex [$F(1, 148) = 0.322, p = 0.571 > 0.05$]. Male students scored significantly higher

($M = 42.57$, $SD = 11.45$) than females ($M = 36.86$, $SD = 10.61$), $p = 0.002 < 0.05$; the effect size is regarded to be moderate (eta squared = 0.06).

Considering that 48 % of the age cohort of lower secondary school students in Poland continue schooling in general upper secondary school (Eurydice 2014), an analysis of the results of these highly cognitively able students from lower secondary school ($n = 34$, $M = 42.35$, $SD = 6.45$) revealed no statistically significant differences in TL between groups ($p = 0.17 > 0.05$). Across sex, significant differences in TL were found ($p = 0.03 < 0.05$). Males scored higher than females ($M_m = 45.72$, $SD_f = 9.14$; $M_f = 42.05$, $SD_f = 9.18$; respectively). No markedly effect of schooling in general upper secondary school on TL improvement was detected.

Students scored differently across TL dimensions. The highest average score was reported for knowledge, as expected, while problem-solving capacity and CTDM ability were lower than knowledge. Real-life concrete problems in the TL test seem to be difficult for students, and those with a previous experience in real-life problems had an advantage in the test. CTDM skills thus need to be more developed. The gender effect was not significant ($p > 0.05$) among lower secondary school students, while general upper secondary school students differ significantly across gender, with males scoring significantly higher in terms of capacity and CTDM, ($p = 0.03 < 0.05$, eta squared = 0.03; $p = 0.00 < 0.05$, eta squared = 0.11, respectively).

Structural equation modelling analysis

A path model consists of student performance variables (GPA and TL) 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 learners (Avsec and Szewczyk-Zakrzewska 2015; Friedel and Rudd 2006; Kappe and Van der Flier 2012; Ogot and Okudan 2006; Richardson et al. 2012), while global, self-motivated, and visual learners have an advantage in TL (Carmo et al. 2006; Chase et al. 2007; Cox 2013; Galotti et al. 2006; Gregorc 2006; Tezel and Casakin 2010). Until now, clear empirical evidence was still lacking. We thus constructed a path model of effective training outcomes influenced by independent variables. Model fit tests were done in AMOS software, and a path model of GPA and TL and their influencing factors along with statistically significant ($p < 0.05$) standardised path coefficients is shown in Fig. 1. Exogenous entries in the model were learning styles, while endogenous variables were GPA and TL. All

Table 2 TL and its descriptive statistics across type of group and sex ($n = 150$)

Group	Sex	Number of students	TL		Knowledge		Capacity		CTDM	
			M (%)	SD (%)	M (%)	SD (%)	M (%)	SD (%)	M (%)	SD (%)
Lower secondary school	Male	35	35.51	8.69	55.84	13.61	33.10	13.17	19.29	10.84
	Female	36	32.78	9.17	49.75	15.74	31.71	12.68	18.29	10.69
	Total	71	34.12	11.45	52.75	14.94	32.39	11.53	18.78	10.70
Upper secondary school	Male	34	48.18	10.26	60.30	15.00	42.61	13.71	39.39	13.98
	Female	35	41.06	10.11	56.72	15.70	35.24	14.18	25.95	11.62
	Total	79	45.03	10.74	58.61	15.39	39.35	14.21	33.44	13.62

exogenous variable effects were hypothesised 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 standardised path coefficients ($p < 0.05$). According to commonly used fit indices (Blunch 2013; Schermelleh-Engel et al. 2003), we found the fit of this model to be very close. A non-significant p value (0.74) was observed from the Chi squared test (7.72), and the Chi square divided by its degrees of freedom was less than 5 (0.70). The goodness-of-fit index, the comparative fit index, and the Tucker–Lewis Coefficient values were greater than 0.95 (0.99, 1.0, and 1.05, respectively), while the root mean-squared error of approximation and the root mean square residual were less than 0.05 (0.00 and 0.004, respectively). The probability of close fit was greater than 0.05 (0.91). The probability level of the test of close fit was also higher than the proposed threshold level of 0.50 for a good model fit (Blunch 2013). This indicates the model to be effective and not in need of any improvement. All paths in the model showed significant effects.

The significant ($p < 0.05$) path coefficients varied from small (0.08) to strong (0.37), and the absolute rate was considered. The variance in academic achievements was

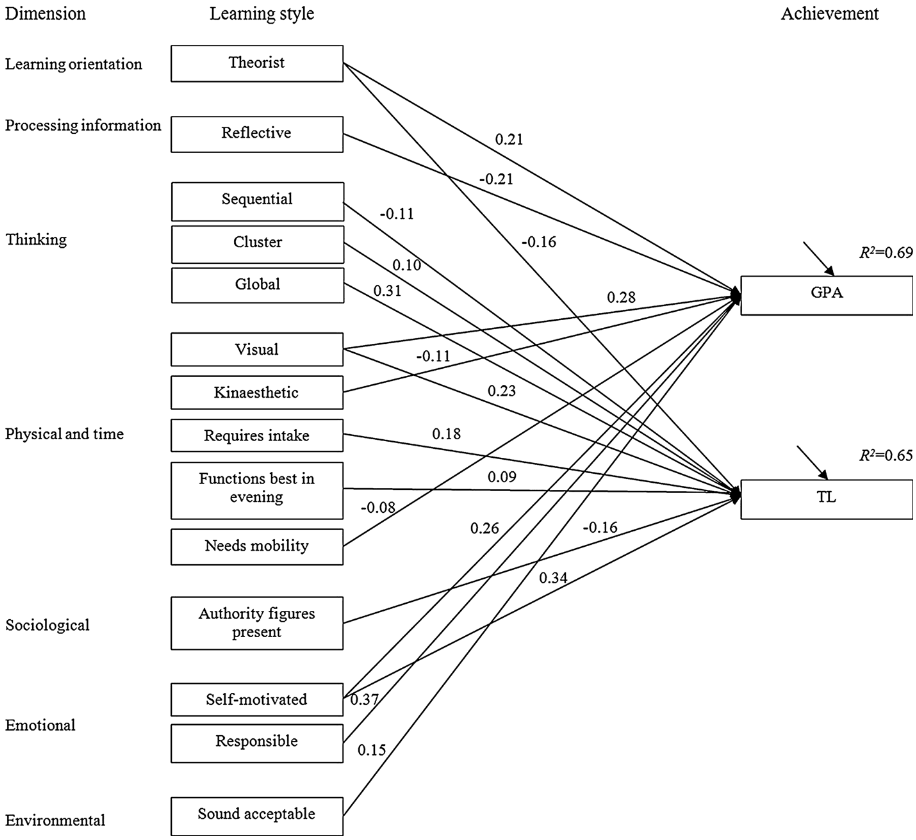

Fig. 1 Path model of GPA and TL and their influencing factors with significant ($p < 0.05$) standardised path coefficients ($n = 150$)

explained by influencing variables in 69.2 % of cases. The most influential variables were *responsible, visual,* and *self-motivated learners* (0.37, 0.28, and 0.26, respectively), which most positively predict GPA, while the learning *style of reflective learners* significantly predicts GPA with a negative correlation (−0.21). The variance of TL was explained for 64.7 % of cases by influencing variables of learning styles. *Self-motivated, global,* and *visual learners* contribute highly to TL (0.34, 0.31, and 0.23, respectively) while the most negative predictors were learning styles with a great need for *authority figures*, *theorist*-learning orientations, and, surprisingly, *sequential thinkers*, which was unexpected (−0.16, −0.16, and −0.11, respectively). Six path coefficients had negative estimates. A high level on these learning styles scale predicts poor student achievements considering GPA and TL.

The explained variances were calculated using R^2 from the path model where $R^2 = 0.02$ means a small impact, $R^2 = 0.13$ a medium effect size, and $R^2 = 0.26$ a large effect size (Cohen et al. 2003).

Discussion

The purpose of this study was to investigate whether learning styles significantly predict academic success and TL in secondary school students. The investigation of students' learning styles considering the multiple modalities of a composite model yielded interesting results.

Secondary students are evenly distributed according learning orientation and processing information, as expected. Surprisingly, we found many cluster thinkers, which confirms Karnofsky's idea of introducing the cluster learning style as an important tool to identify concrete learners who are able to take more risks and who are generally superior in reaching good conclusions, although they are harder to describe and model explicitly (Karnofsky 2014). Such learners are very important in advancing creativity for innovations (Houtz et al. 2003; Kirton 1994). We revealed the kinaesthetic preferences of students, which might lead to procrastination behaviour (Richardson et al. 2012) and reduce GPA, while a lack of mastery goal orientation, the need for authority, and the avoidance of problem solving might also reduce TL (Gholami and Bagheri 2013; Houtz et al. 2003).

TL of secondary students seems to be poor, with the exception of the knowledge component that is regarded to be satisfactory. A lack of learning standards not adjusted to the standards of TL is evident. An absence of technology and engineering subject matter in general upper secondary school resulted in minor progress in TL regarding their lower secondary school counterparts.

A path model revealed that responsible (conforming), self-motivated, visual, and theorist learning styles are the best positive predictors in self-reported GPA (0.37, 0.28, 0.26, and 0.21, respectively). The conforming learning style was expected to be decisive, as confirmed by the findings of Richardson et al. (2012). Reflective processing information was found to be a negative predictor in self-reported GPA, as confirmed by the findings of Friedel and Rudd (2006) and Kappe and Van der Flier (2012). This points to a learning environment that is not particularly busy, with a structured manner of instruction, and with less opportunities for reflection during the instruction or afterwards through student feedback (Gregorc 2006). It also indicates the small amount of reflective work among students, and long assignments with more factual and procedural knowledge learning objectives, as included in the GPA (Gregorc 2006; Krathwohl 2002). Visual learners significantly ($p < 0.001$) and positively predict GPA (0.28) and TL (0.23), and can benefit from a diversity of learning objects in a technology-intensive learning environment (Avsec and Szewczyk-Zakrzewska 2015; Houtz et al. 2003; Mohamad et al. 2011; Ogot and Okudan 2006).

Mastery goal orientation (self-motivated learners) and global thinkers are the best positive predictors of TL (0.34 and 0.31, respectively), thus we confirm the findings of several studies (Carmo et al. 2006; Galotti et al. 2006; Houtz et al. 2003; Kirton 1994; Tezel and Casakin 2010). Best solved item was the knowledge dimension, especially conceptual and metacognitive items, in which global learners prevailed, which confirms the findings of Gregorc (2006) and Pintrich (2002). Items at the capacity dimension of TL were mostly related to real-life problems as well as drawings, as visual, concrete, and active (global) learners benefit here, which supports the findings of Powell (2009) and Carmo et al. (2006). The best negative correlated predictors in TL were namely a need for authority (−0.16) and a theorist learning orientation (−0.16). A lack of self-confidence, inquisitiveness, maturity, and open-mindedness also reduce TL, which confirms the findings of Ruud et al. (2006). Abstract sequential learners (theorists) need more structure and opportunities for problem solving and prefer algorithmic behaviours, which is not effective for real-life technical problems and decision-making as previously identified (Cox 2013; Galotti et al. 2006; Gregorc 2006; Karnofsky 2014). Concrete sequential learners prefer to avoid decision-making (−0.11), which confirms the finding of Chase et al. (2007).

Surprisingly, the learners who prefer sound positively contribute to GPA (0.15), even if they are right-preferenced students who are other-motivated, need authority, and are less persistent (Dunn 1983). A significant ($p = 0.04 < 0.05$) contribution of cluster thinkers to TL was detected. It seems that cluster thinkers are closer to global learners, and that a cluster-thinking style seems to prevent some obviously problematic behavior relating to knowledge-impaired judgment in students. We thus confirm the findings of Karnofsky (2014) and justify the introduction of this thinking style into DLSI.

This study was conducted in light of the following primary limitations, namely that the curriculum and learning standards in Polish secondary schools are not yet adjusted to the standards of TL. Thus, achievements in TL, especially at capacity and the CTDM dimension of TL, were expected to be low. Other limitations could relate to the quality of the programme, teacher effects, and student performance in traditional academic courses.

Conclusions

This study indicated that learning styles were significant ($p < 0.05$) predictors of academic success and creativity gain. A composite dynamic learning style inventory was proved as a reliable and valid instrument.

Highly conforming learners and visual and self-motivated theorists might potentially be offered more challenging honours programmes with corresponding special commendations on their projects and research work. Students who are more reflective, kinaesthetic, and with a need for mobility could receive more unstructured instruction in a busy environment with holistic learning objects, which offer innovative experiences and many associations. Reflectors need frequent deadlines as well as shorter and group assignments where more conceptual and meta-cognitive knowledge learning objectives are included; they should also be given fewer second chances for passing examinations. Reflective learners must be given information in a detailed, systematic, and reasoned manner.

Mastery goal oriented, global, and visual learners should receive more challenging tasks, especially on the higher cognitive levels of Bloom's taxonomy, and they must be engaged in groups for research and development of innovative products and services. Assimilators who prefer authority figures must be taught with more substance and sequence and be given more textual, inquiry-based, and criterion-referenced instruction; they also need a quiet environment and enough time to complete the activity or assignment. They should be assigned more abstract problems and unconstrained design conditions where self-paced learning is enabled.

We hope these findings lead the way towards more nuanced tests of the relations among learning styles, academic success, and TL, especially in secondary education. The practical implications of this study are that secondary schools should collect learning style data at the beginning, then help students accordingly to be more successful and technologically literate. Further research is required to replicate these findings among other and larger samples, especially where more evidence of active teaching methods is found. Gender effects should be investigated accordingly. We also propose the introduction of aptitude tests along with self-reported GPA as part of the cognitive dimension.

Acknowledgments The authors wish to thank the *Gimnazjum nr 6*, *Gimnazjum nr 22, VIII Liceum Ogólnokształcące, XX Liceum Ogólnokształcące*, and the Pedagogy and Psychology Centre at Cracow University of Technology, Cracow, Poland, for their help in obtaining the valuable data for the research.

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