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Flexible thinking in learning: An individual differences measure for learning in technology-enhanced environments

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ABSTRACT

In an era of global changes, flexible thinking is a key competency, necessary for learning in technology-enhanced environments. Advancements in instructional science and educational technologies call for an updated conceptualization of 'flexible thinking' to address current educational challenges. Echoing this need, the goal of this study was to reconceptualize flexible thinking and to generate a valid and reliable instrument for measuring an individual's inclination to think flexibly in contemporary learning situations. A Six-stage study was designed to assess and validate the new instrument. As a result, the Flexible Thinking in Learning (FTL) scale was generated, consisting of three subscales: Acceptance of new or changing technologies, Open-mindedness to others' ideas, and Adapting to changes in learning situations. Within the framework of the current study, findings confirmed the FTL scale's content, construct, and concurrent validity, indicating stability across populations and over time. Consequently, the FTL scale may serve as both a research instrument and a self-assessment tool. It may assist in the evaluation of learners' inclination to think flexibly or in explaining individual differences regarding the utilization of new learning methods. Yet, generalizability should be carefully considered and additional studies should be conducted to examine the FTL scale among learners from different age groups and academic background.

1. Introduction

In the age of rapid educational and technological changes, learners are required to think flexibly and adapt to new ways of learning and communicating (Barak, Watted, & Haick, 2016; Griffin, McGaw, & Care, 2012; NRC, 2012a). Flexibility is one of many skills necessary for success in work, life, and learning in the 21st century (OECD, 2013; P21, 2009). In this study, we focused on "flexible thinking" since it receives little attention in comparison to other 21st century skills, such as: creative thinking (e.g. Navarrete, 2013), critical thinking (e.g. Kong, 2015; Lee, 2015), or problem solving (e.g. Chao, 2016; van Merriënboer, 2013). The following sections provide some insights into the way 'flexibility' was conceptualized in past studies, indicating a need for a more up-to-date definition, with an emphasis on technology-enhanced learning.

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1.1. Conceptualization of flexible thinking

Studies in the 1960's and 1970's, considered 'flexibility' as one of the four basic functions of divergent thinking, together with elaboration, fluency, and originality (Guilford, 1967; Torrance, 1974). According to this approach, flexibility is described as the variety of categories or themes generated while producing an idea. It is also described as the number of ideological shifts in thinking (Torrance, 1974). The definitions of 'flexible thinking', used interchangeably with the term 'cognitive flexibility', are varied. Spiro and Jehng (1990) viewed cognitive flexibility as "the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands" (Spiro & Jehng, 1990, p. 165). According to studies in psychology, cognitive flexibility is considered as a higher order thinking skill and an aspect of executive functions (Garner, 2009). It concerns instantaneous consideration of multiple perspectives and the ability to make changes in one's thoughts or beliefs (Garner, 2009). More recently, the Assessment and Teaching of 21st Century Skills project, addressed flexibility as part of the 'ways of thinking' domain, indicating the need for educating people to become "open and fair minded, flexible in considering alternative opinions" (Griffin, McGaw, & Care, 2012, p.40).

In a social perspective, flexible thinking is conceptualized as the ability of an individual in a group to collectively assess her/his own behavior, and make the required adjustments for effective functioning (McComb, Green, & Dale Compton, 2007). The Organization for Economic Cooperation and Development (OECD, 2009) viewed flexibility and adaptability as examples of essential competencies in the context of collaboration and teamwork. Similarly, the Partnership for 21st Century Skills (P21, 2009) conceptualizes flexibility as willingness to make necessary compromises in order to accomplish a group's common goal. It is referred to as being flexible in incorporating feedback effectively, dealing positively with praise, setbacks, and criticism. It is described as the ability to understand, negotiate, and balance diverse views and beliefs to reach workable solutions, particularly in multi-cultural environments (P21, 2009). Interpersonal flexibility positively affects group work and the members' ability to collaborate (McComb et al., 2007; P21, 2009).

In the context of education, flexible thinking is a key competency necessary for adapting to new learning environments, for transferring knowledge to new situations, and for understanding and solving unfamiliar problems (OECD, 2013; P21, 2009; Spiro, Collins, & Ramchandran, 2007). Resent studies suggested modifications, calling for a comprehensive conceptualization of 'flexibility' while emphasizing a more contemporary approach (DeYoung, Peterson, & Higgins, 2005; Garner, 2009; Ionescu, 2012). Such an approach is relevant to technology-enhanced learning environments that are supported or facilitated by web-based technologies and mobile devices (Barak & Ziv, 2013; Plesch, Kaendler, Rummel, Wiedmann, & Spada, 2013). In the realm of contemporary education, the need for re-conceptualization of "flexible thinking" is reinforced in light of recent developments in information and communication technologies.

1.2. Flexible thinking in technology-enhanced learning

Guided by recent studies, we identified three main factors that may indicate a learners' dispositional inclination to think flexibly in technology-enhanced learning: Acceptance of new or changing technologies (Technology acceptance), Open-mindedness to others' ideas (Open-mindedness), and Adapting to changes in learning situations (Adapting to new situations). The three factors are described in the following paragraphs.

1.2.1. Technology acceptance

The development of advanced information and communication technologies (ICTs) together with mobile devices (e.g. laptop computers, tablets, and smart phones) has changed the way teaching and learning are conceptualized and conducted (Barak, 2014; Barak et al., 2016; Barak & Ziv, 2013; OECD, 2013). Technology-enhanced learning is a common practice nowadays, describing learning activities or environments that are mediated, supported, facilitated, or augmented by web-based technologies and mobile devices (Barak, 2007; Plesch et al., 2013). Technology-enhanced learning promotes active and ubiquitous learning, location-based learning, and the generation of learning communities (Barak, 2012; 2014; Plesch et al., 2013; Rafaeli, Barak, Dan-Gur, & Toch, 2004). As ICTs continue to develop, new learning methods evolve, requiring learners to be flexible in their ability to use them efficiently (Barak, 2014). Hence, technology acceptance and adoption, in various contexts, is a main factor of contemporary flexible thinking in learning (P21, 2009).

Following the need to examine an individual's ability to accept and adopt new technologies, the Technology Acceptance Model was generated (e.g. Davis, 1989; Edmunds, Thorpe, & Conole, 2012; Legris, Ingham, & Collerette, 2003; Venkatesh & Bala, 2008). This model consists of four constructs: perceived ease of use, perceived usefulness, attitudes toward using technology, and behavioral intention (Davis, 1989). Perceived ease of use is the degree to which a person believes that using a particular system will be free from effort, while perceived usefulness signifies the degree to which a person believes that using a particular system will enhance their performance (Davis, 1989). Attitude toward using is the degree to which a person prefers a particular technology, and behavioral intention is the degree to which a person is open and willing to use a particular technology (Davis, 1989; Legris et al., 2003). Flexible thinkers are open to new experiences and therefore are more likely to accept and adopt new technologies (Barak, 2014; Legris et al., 2003). In this study, relevant items of the Technology Acceptance Model were incorporated and slightly modified to reflect the first facet of flexible thinking in learning.

1.2.2. Open-mindedness

Open-mindedness is a multifaceted construct that includes the willingness to change one's beliefs in the face of contradictory evidence (Baron, 1991). It is conceptualized as a flexible approach to alternative views and perspectives (Baron, 1991; Harding & Hare, 2000; Stanovich & West, 1997). Open-mindedness is the ability to consider new possibilities, different opinions, and alternative explanations (Stanovich & West, 1997). Openness and flexibility are thought of as two sides of the same coin – structure and process, antecedent and consequent (Spiro et al., 2007). Openness to experience is one of five personality traits mentioned in the Five Factor Model together with neuroticism, extraversion, agreeableness, and conscientiousness (McCrae & John, 1992). Individuals who think flexibly are open to new ideas and exhibit greater success in dealing with life changes (Whitbourne, 1986); they process new information and explore new environments easily (DeYoung et al., 2005).

Open-mindedness is significant for meaningful learning; it is the opposite of rigidity and oversimplification that impair learning and teaching (Spiro et al., 2007). When discussing flexible thinking in learning, it is important to consider learners' habits of mind. The way learners think; their worldviews, and their mindsets, impact on their ability to construct knowledge. People often view the world as made up of orderly, predictable, and well-structured events (Spiro et al., 2007). Hence, in learning situations, learners often adhere to simple generalization of the learning topics, using a schema or a prototype example. However, when presented with an authentic and complex problem, they might find it difficult to solve. Therefore, it is important to provide learners with open and complex problems, exposing them to alternative views and contradictory data that encourage open-mindedness and flexible thinking (Baron, 1991; Spiro et al., 2007). In this study, relevant items of the Open-Minded Thinking questionnaire (Stanovich & West, 1997) were incorporated and slightly modified to reflect the second facet of flexible thinking in learning.

1.2.3. Adapting to new or changing situations

Rapid changes in the way people communicate and construct knowledge require the ability to adapt to new situations. Ployhart and Bliese (2006) defined adaptability as "an individual's ability, skill, disposition, willingness, and/or motivation, to change or fit different task, social, and environmental features" (p.13). In contemporary education, adaptability is thought of as an essential skill since students are required to use new learning methods, environments, and tools (OECD, 2013; P21, 2009). One characteristic of adaptability is the willingness to be involved in an unfamiliar situation. This can be a new learning topic, a new learning environment, or a new problem to solve. As part of flexible thinking, adaptability allows a learner to engage with these unfamiliar situations in an efficient way. It explains students' ability to transfer what they have learned to new situations, since flexible learners are prepared to challenge the unknown and face the unfamiliar (Bransford, Brown, & Cocking, 2000). In the context of collaboration and team work, flexibility and adaptability are related competences (OECD, 2009; P21, 2009). Adaptive responses to changing demands and the ability to spontaneously restructure one's knowledge are important for a successful teamwork (P21, 2009). Flexible thinkers adapt easily to varied roles, responsibilities, schedules, and contexts. They work effectively and respectfully with diverse teams by making necessary compromises to accomplish a common goal (P21, 2009).

The inherent link between flexibility and adaptability is signified in various measurement tools. Martin and Rubin (1995) designed a scale for cognitive flexibility that includes 'willingness to adapt to a certain situation' as one of its main features. This scale also includes features such as: 'awareness that in any given situation there are alternative options' and 'self-efficacy in the ability to be flexible'. However, this scale lacks references to open-mindedness and technology acceptance, two important components for contemporary conceptualization of flexible thinking (Spiro et al., 2007; OECD, 2013; P21, 2009). A more recent scale – the I-ADAPT, was developed by Ployhart and Bliese (2006) to examine and define adaptability. This scale measures performance in response to changes in the environment. According to the researchers, adaptive performance can be summarized into four main strands: a. coping with stressful events; b. responding to organizational change; c. strategy selection; and d. task performance (Ployhart & Bliese, 2006). The I-ADAPT scale consists of eight dimensions: cultural, learning, creativity, crisis, work stress, physical, uncertainty, and interpersonal. In this study, relevant items of the I-ADAPT scale were incorporated and slightly modified to reflect the third facet of flexible thinking in learning.

To summarize, the studies described above provided the theoretical basis and the methodological framework for generating a scale for measuring an individual's inclination to think flexibly in the context of present-day learning. The need for a new and comprehensive scale evolved due to the fact that existing measurements, as described above, are only partially associated with flexible thinking or do not address current educational challenges that characterize 21st century learning (e.g. Davis, 1989; Martin & Rubin, 1995; Ployhart & Bliese, 2006).

2. Research goal and design

Advancements in instructional science and educational technologies necessitate a more up-to-date definition of flexible thinking, with an emphasis on contemporary learning. Hence, the goal of this study was to re-conceptualize flexible thinking and to generate a valid and reliable instrument for measuring individual's dispositional inclination to think flexibly in contemporary learning. This raises the following question: how should flexible thinking in learning be conceptualized and measured?

This study included six stages that were conducted in order to assess and verify the validity and reliability of the Flexible Thinking in Learning (FTL) scale. These stages are customary in the process of developing a new measuring tool (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011; Oreg, 2003). The first stage assessed the FTL scales' content validity by examining inter-rater agreement among eight experts in instructional science. The second stage assessed construct validity, using exploratory and confirmatory factor analysis methods. Stages three and four determined the FTL scale's discriminant and known-groups validity by examining differences between and correlations among other scales. Stage five established the FTL scale's stability over populations and time, providing good fit to the empirical data. Stage six indicated the scale's concurrent validity through triangulation with participants' actual practice. For data analysis, we used IBM Statistical Program for the Social Sciences (SPSS), version 22.0 (IBM, 2013). Table 1 summarizes the study's six stages, the analysis method applied in each stage, and the participants.

The students' experience in technology-enhanced learning environments varied according to the different courses they took. In general, they all used an online learning management system (Moodle), experienced the use of collaborative writing platforms (e.g. Google Docs), and used mobile devices (laptops or tablets).

The following sections describe the six stages of the FTL scale's validity and reliability analysis. Each stage details the analysis purpose, method, and findings.

2.1. Stage 1: Establishing the content validity of the FTL scale

In this exploratory stage, several sources for flexible thinking were used to generate the initial items for the FTL scale. The purpose of this stage was to examine the extent to which these items represent flexible thinking in learning. Applying a quantitative approach to content validity (Lawshe, 1975), this stage was designed to ensure that the FTL scale's items truly measures dispositional inclination to think flexibly.

2.1.1. Stage 1: Method

We generated a pool of 22 items adapted from or inspired by validated scales (Davis, 1989; Ployhart & Bliese, 2006; Stanovich & West, 1997; Venkatesh & Bala, 2008). Each item related to one of the three components of flexible thinking in learning: Technology acceptance, Open-mindedness, and Adapting to new situations. Our first subscale – Technology acceptance, included five items; four adapted from the Technology Acceptance Model (TAM) questionnaire, which measures technology usefulness and ease of use (Davis, 1989; Venkatesh & Bala, 2008). Building on the literature, we generated a fifth item: 'I like experiencing new learning technologies' which indicates a positive inclination towards acceptance of new technologies. Our second subscale – Open–mindedness, included eight items adapted from the Open-Minded Thinking (AOT) questionnaire (Stanovich & West, 1997). These items were adapted from: 'willingness to consider evidence contradictory to beliefs' and 'willingness to consider alternative opinions and explanations'. They were rephrased to reflect open-mindedness in the process of learning. Our third subscale – Adapting to new situations, included nine items adapted from the I-ADAPT scale (Ployhart & Bliese, 2006). The items were influenced by the subscale of uncertainty (e.g. 'I can adapt to changing situations') and were modified to reflect learning processes.

The 22 items were closely examined by eight assessors, according to their relevance to flexible thinking in learning. All the assessors were experts in instructional science with PhD or MSc degrees. Their ratings were on a scale of: (3) essential, (2) useful but not essential, or (1) not necessary. The content validity ratio (CVR) was calculated for each item, using Lawshe (1975) equation:

$CVR = (E - N/2)/(N/2)$; where N is the total number of assessors and E is the number of assessors who rated the item as essential. In addition, agreement percentage and Fleiss kappa were calculated to indicate inter-rater agreement among multiple raters (Fleiss, 1971).

2.1.2. Stage 1: Findings

From the pool of 22 items, 18 were indicated by all assessors as 'essential' according to their relevance to flexible thinking in learning. Two items (no. 17 and 22) were indicated as 'essential' by seven assessors and two items (no. 6 and 14) were indicated as 'essential' by only six assessors. The content validity ratio (CVR) for each item in the FTL scale is presented in Table 2.

Table 2 shows that the CVR ranged from 0.50 to 1.00. Items with a CVR value of 1.00 were kept; those with a CVR value of 0.75 were slightly rephrased, according to the experts' suggestions. Items with a CVR of 0.50 (# 6 and 14) were discarded.

Table 1
Six stages of the Flexible Thinking in Learning (FTL) scale.

Stage	Analysis method	Participants
1. Content Validity	Inter-rater agreement	Experts in instructional science (N = 8)
2. Construct validity	Exploratory and confirmatory factor analysis	Undergraduates in education (N = 429)
3. Discriminant validity	Correlations between scales	Teaching diploma students (N = 363)
4. Known-groups validity	Differences between subgroups	Teaching diploma students (N = 363)
5. Stability across populations and time	Differences between repeated measurements	Undergraduates from two universities (N = 225)
6. Concurrent validity	Triangulation with actual practice	Undergraduates (N = 54)

Table 2
Content validity ratio for each item.

	Items	Essential[a]	CVR[b]
1	I adjust quickly to new learning technologies	8	1.00
2	I adjust easily to technological changes as software updates	8	1.00
3	I am open to updates in new technological tools that can help me learn	8	1.00
4	I use various technological tools for learning and frequently change between them.	8	1.00
5	I like to experience new learning technologies	8	1.00
6	I get confused by the opinions of others	6	0.50
7	When learning, I listen to various opinions even if they contradict my opinion	8	1.00
8	Even when I am convinced I am right, I listen to other learner's opinions	8	1.00
9	In a learning process, I am open to feedback and criticism	8	1.00
10	When learning, I tend to consider various possibilities	8	1.00
11	When learning, I observe things from different perspectives	8	1.00
12	For deep learning, I tend to examine diverse viewpoints	8	1.00
13	It is important that different viewpoints will be expressed in the learning process	8	1.00
14	I feel blocked whenever I need to make changes in learning	6	0.50
15	I adjust myself to changes in learning conditions without difficulty	8	1.00
16	I adjust easily when ways of learning change	8	1.00
17	I do not have trouble getting used to new learning situations	7	0.75
18	I adjust to different learning situations	8	1.00
19	I am open to changes in my ways of learning even if it requires effort and work	8	1.00
20	In any given learning situation I adapt to circumstances	8	1.00
21	I am open to new experiences in learning	8	1.00
22	I am open to learning in various ways	7	0.75

[a] The number of experts (out of eight) who rated the item as essential.
[b] CVR - content validity ratio.

Agreement among raters was high: 92.1% with Fleiss kappa of 0.63. At the end of this stage, the final FTL scale included 20 items that were formatted on a Likert type scale, ranking from 1 (strongly disagree) to 6 (strongly agree).

2.2. Stage 2: Establishing the construct validity of the FTL scale

The purpose of this stage was to examine the construct validity of the FTL scale by applying exploratory and confirmatory factor analysis (Cronbach & Meehl, 1955; Little, 2013). First, an exploratory factor analysis was conducted, by applying the principle component analysis (CPA) approach, to examine cross-loadings and select items with a high factor loading (>0.45). The term 'exploratory factor analysis' is used as a generic expression for variable reduction techniques (e.g. Glynn et al., 2011; Nunnally & Bernstein, 1994; Oreg, 2003). Second, a confirmatory factor analysis was conducted, by applying a structural equation modeling (SEM) approach, to confirm the factor structure and test the theoretical model.

2.2.1. Stage 2: Method

The FTL scale was distributed as an online questionnaire among undergraduate students who were enrolled in a variety of education courses. Four hundred and twenty nine participants from two higher education institutions responded. Eighty-five percent were women, and fifteen percent were men, and their age ranged from 18 to 33 years ($M = 24$, $SD = 9.7$). The high percentage of female respondents is in line with the female/male ratio in many undergraduate education programs (AACTE, 2013). No statistically significant differences were found between the participants from the two institutions in their age groups or mean item scores.

The exploratory factor analysis was conducted by using the principle component analysis approach as a variable reduction technique to identify the number of latent constructs and the underlying factor structure for the FTL scale. The principal component analysis was used as the extraction method, and the Varimax with Kaiser normalization was used as the rotation method.

The confirmatory factor analysis was conducted using a second order latent factor representing the FTL scale, and three first-order latent factors, each representing one of the FTL components that were identified in the first stage. The AMOS™ 16.0 system was used for establishing the uni-dimensionality, validity, and reliability of the latent constructs.

2.2.2. Stage 2: Results

The exploratory factor analysis of the 20 items revealed a three-factor solution. All items, except one: 'I am open to learning in various ways', were loaded significantly on at least one factor. This item was deleted as it was not loaded on any factor. The factor analysis was run again on the remaining 19 items, revealing a three factor solution in accordance to the three flexible thinking components identified in the literature: Learning technologies acceptance (TA) - 5 items, open-mindedness in learning (OM) – 7 items, and adapting to new learning situations (AL) – 7 items (Table 3).

The three factors presented in Table 3 explain 60.00% of the total variance. Total scale's reliability coefficient alpha (Cronbach's) was 0.91. Alphas for the Learning technologies acceptance, the open-mindedness, and the adapting to new

Table 3
Flexible Thinking in Learning factor loadings (N = 429).

60.00% total variance explained (α = 0.91)	Factor loadings			Corrected item-total correlation
Item	F1	F2	F3	
Learning technology acceptance (TA) 40.6% variance explained (α = 0.90)				
I adjust quickly to new learning technologies	0.846			0.81
I adjust easily to technological changes as software updates	0.820			0.78
I am open to updates in new technological tools that can help me learn	0.794			0.76
I use various technological tools for learning and frequently change between them.	0.778			0.70
I like to experience new learning technologies	0.761			0.71
*Open-mindedness in learning (OM)*10.5% variance explained (α = 0.84)				
When learning, I listen to various opinions even if they contradict my opinion		0.795		0.60
Even when I am convinced I am right, I listen to other learner's opinions		0.746		0.61
In a learning process, I am open to feedback and criticism		0.712		0.60
When learning, I tend to consider various possibilities		0.660		0.67
When learning, I observe things from different perspectives		0.627		0.61
For deep learning, I tend to examine diverse viewpoints		0.563		0.60
It is important that different viewpoints will be expressed in the learning process		0.461		0.51
*Adapting to new learning situations (AL)*8.9% variance explained (α = 0.83)				
I adjust myself to changes in learning conditions without difficulty			0.755	0.65
I adjust easily when ways of learning change			0.720	0.67
I do not have trouble getting used to new learning situation			0.635	0.34
I adjust to different learning situations			0.631	0.67
I am open to changes in my ways of learning even if it requires effort and work			0.616	0.69
In any given learning situation I adapt to circumstances			0.609	0.56
I am open to new experiences in learning			0.539	0.63

learning situations subscales were all acceptable (0.90, 0.84, and 0.83, respectively). Consequently, Spearman correlation analysis was conducted. The results are presented in Table 4.

Table 4 shows significant positive correlations between each pair of variables, indicating that the three factors relate to the same construct but are still distinctive. The existence of moderate-to-high correlations among factors also reflects the existence of a general disposition to flexible thinking in learning.

Our next step was to conduct a confirmatory factor analysis on the remaining 19 items. Item standardized regression weight estimates for FTL three-factor model ranged from: 0.719 to 0.884 on the *Learning technologies acceptance* items; from 0.531 to 0.806 on the *Open-mindedness in learning* items; and from 0.610 to 0.795 on the *Adapting to new learning situations* items. All loadings were significant at $p < 0.001$ level. According to cutoff criteria for fit indexes (Hu & Bentler, 1999), the three-factor model presented good fit to the empirical data: $\chi^2(130, N = 429) = 267.7$, $p = 0.000$; Goodness of Fit Index (GFI) = 0.94; Tucker–Lewis Index [TLI] = 0.96; Comparative Fit Index [CFI] = 0.97; Root-Mean-Square Error of Approximation [RMSEA] = 0.05. These results reinforce the construct structure obtained in the previous stage.

In addition, a structural equation modeling of the FTL scale indicated statistically significant relationships between the three factors (Fig. 1).

Fig. 1 presents a model with three latent variables – OM, TA, and AL, and their regression weights (one-headed arrows). Our findings place *open-mindedness in learning* as a predictor to both *learning technologies acceptance* and *adapting to new learning situations*. This means that an individual with a high inclination to be open to new ideas and experiences will most likely try new learning technologies and easily adapt to new ways of learning. Moreover, *learning technologies acceptance* was found to be a predictor of *adapting to new learning situations*. Our model suggests that a student's capability to adapt to new learning situations is predicted by both open-mindedness and his willingness to use new learning technologies.

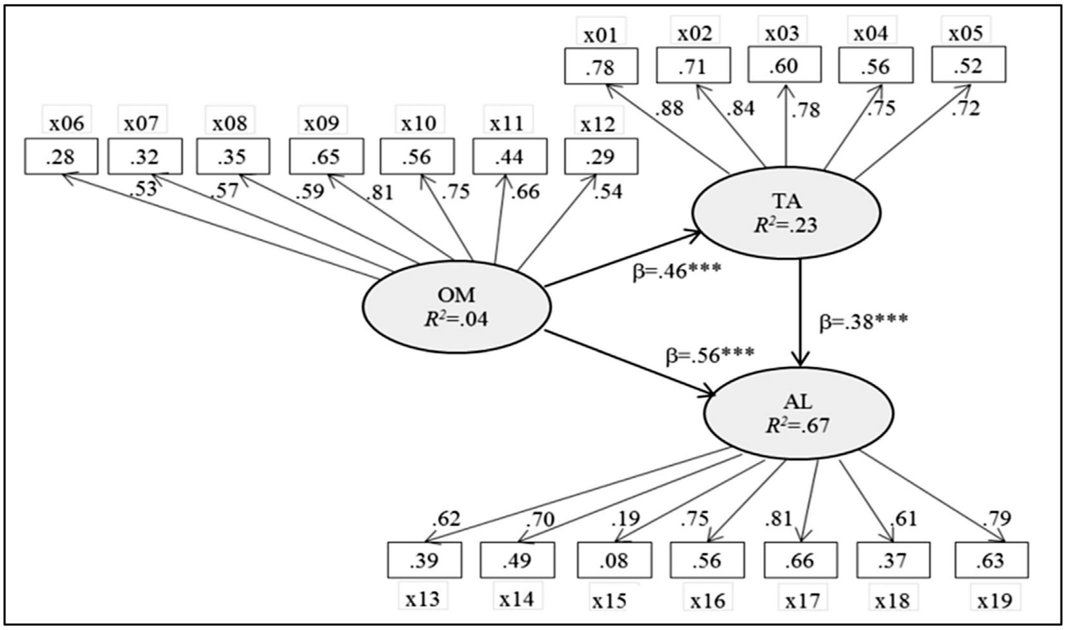
2.3. Stage 3: Determining FTL's discriminant validity

The purpose of this stage was to establish the FTL scale's discriminant validity by examining correlations with another validated measure (Messick, 1989). Flexible thinking encompasses open-mindedness and therefore can be recognized as the quality opposite to resistance to change (Oreg, 2003). Therefore, in this stage, we administered the FTL scale together with the

Table 4
Means, standard deviations, and correlations of FTL subscales (N = 429).

Factor	M[a]	SD	1	2	3
Learning technologies acceptance (TA)	4.41	0.98	–		
Open-mindedness in learning (OM)	4.76	0.69	0.50***	–	
Adapting to new learning situations (AL)	4.37	0.74	0.54***	0.55***	–

***p < 0.001.
[a] Range 1–6 (6 = high level of Flexible Thinking in Learning).



*** *p<.001*

Fig. 1. FTL Scale confirmatory factor analysis via structural equation modeling.

Resistance to Change (RTC) scale, designed to measure an individual's dispositional inclination to resist changes (Oreg, 2003). We expected to receive significant negative, yet moderate, correlations, as the RTC traits: routine seeking, emotional reaction, short-term focus, and cognitive rigidity, signify individuals' general attitudes toward change and not necessarily their specific inclination to think flexibly while learning.

2.3.1. Stage 3: Method

Three hundred and sixty-three undergraduate students who studied for a teaching diploma participated in this study. Eighty-eight percent were female, and twelve percent were men, and their age ranged from 20 to 35 years ($M = 26$, $SD = 8.7$). The participants were asked to complete both the FTL and RTC online questionnaires. The RTC scale consisted of 17 items (e.g. 'I like to do the same old things rather than try new and different ones'), compiled into four factors: routine seeking, emotional reaction, short-term focus, and cognitive rigidity (Oreg, 2003). Similar to the FTL scale, the RTC items were ranked on a 6-point Likert type scale from 1 (strongly disagree) to 6 (strongly agree).

2.3.2. Stage 3: Results

The reliability for the RTC scale via Cronbach's alpha was 0.85. The reliability for each subscale was: Routine seeking $\alpha = 0.82$; Emotional reaction $\alpha = 0.75$; and Short-term focus $\alpha = 0.70$. Similar results were reported in the literature (Oreg, 2003). The fourth subscale, Cognitive rigidity, indicated a low reliability coefficient (0.52), and therefore was not included in our study. Table 5 presents the means, standard deviations and Pearson's correlations between FTL and RTC scales and subscales.

Table 5 shows significant high correlations between the FTL scale and its subscales (ranging from 0.81 to 0.89). It also shows significant moderate-to-high correlations between the three FTL subscales (ranging from 0.52 to 0.63). These results are similar to these obtained in the second stage of our study. This supports our assumption that the three factors are dimensions of the same trait, but still distinctive. With regards to the RTC scale, Table 6 shows a moderate significant negative correlation ($r = -0.46$, $p < 0.001$). Significant negative correlations were also found between the FTL and RTC subscales. The *Learning technologies acceptance* (TA) subscale indicated low-to-moderate negative correlations, with the RTC scale and subscales, ranging from −0.24 to −0.56. The *Open-mindedness in learning* (OM) subscale also indicated low-to-moderate negative correlations, with a wider span, from −0.13 to −0.63. The *Adapting to new learning situations* (AL) subscale indicated moderate-to-high negative correlations, ranging from −0.50 to −0.58. These correlations were found to be statistically significantly higher than the correlations between the two other FTL subscales ($Z = 1.96$, $p < 0.001$).

Table 5
Mean, Standard deviations, and Correlations between FTL and RTC scales and subscales (N = 363).

	M^a	SD	1	2	3	4
1. FTL scale	4.50	0.60	–			
2. Learning technologies acceptance	4.44	0.89	0.81***	–		
3. Open-mindedness in learning	4.70	0.61	0.83***	0.52***	–	
4. Adapting to new learning situations	4.36	0.69	0.89***	0.56***	0.63***	–
5. RTC scale	3.01	0.81	−0.46***	−0.33***	−0.23***	−0.58***
6. Routine seeking	3.03	0.76	−0.43**	−0.27***	−0.25**	−0.52***
7. Emotional reaction	3.16	0.99	−0.37***	−0.24***	−0.13*	−0.50***
8. Short-Term Focus	2.99	0.92	−0.43***	−0.27***	−0.24***	−0.53***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
[a] *Range on a 1-to-6 scale.*

Table 6
The effect of learning path, gender and age on the FTL scale and subscales (N = 225).

	MS	F(1, 223)	p	η_p^2
Learning path				
1. FTL scale	0.01	0.03	0.87	0.00
2. Learning technologies acceptance	0.06	0.07	0.79	0.00
3. Open-mindedness in learning	0.04	0.10	0.75	0.00
4. Adapting to new learning situations	0.01	0.02	0.89	0.00
Gender				
1. FTL scale	0.371	0.97	0.32	0.00
2. Learning technologies acceptance	1.60	1.96	0.16	0.01
3. Open-mindedness in learning	0.13	0.33	0.57	0.00
4. Adapting to new learning situations	0.15	0.30	0.58	0.00
Age				
1. FTL scale	0.44	1.15	0.28	0.01
2. Learning technologies acceptance	1.28	1.54	0.21	0.01
3. Open-mindedness in learning	0.56	1.45	0.23	0.01
4. Adapting to new learning situations	0.06	0.11	0.74	0.00

2.4. Stage 4: Establishing FTL's known-groups validity

The purpose of this stage was to assess the validity of the FTL scale according to the known-groups approach (Hattie & Cooksey, 1984). Known-groups validity examines differences between distinct groups that are expected to be different on the measured attribute (e.g. Heimberg & Holaway, 2007). According to this approach, if a questionnaire is valid, one criterion could be that it discriminates between groups that are expected to be different on the measured trait (Hattie & Cooksey, 1984; Heimberg & Holaway, 2007). In this stage, we compared between groups of people with different technology expertise on the FTL scale.

2.4.1. Stage 4: Method

This stage included the same participants as in the previous stage (N = 363). The participants were undergraduate students who studied for a teaching diploma. The majority were female students (88%) and the mean age was 26 ($SD = 8.7$). Guided by the known-groups validity method, we examined the literature for a construct that may lead us to expect differences between two or more groups in their ability to think in a flexible way. Recent literature on 21st century skills associates flexible thinking with individual's inclination to use advanced information and communication technologies (ICTs) (Barak, 2016; Edmunds et al., 2012; NRC, 2012a). This is supported by the work of Devaraj, Easley, and Crant (2008) who maintained that individuals who are open to new experiences are likely to be less threatened by the change implied in adopting novel technology (Devaraj et al., 2008). Therefore, in this stage, the known-groups validity was examined by comparing students' mean scores on the FTL scale with their ICT expertise. The ICT expertise included four distinct groups: a. Generally acquainted with ICTs but prefer not to use them for learning (N = 37, 10%); b. Have some experience with advanced ICTs and use them for learning when necessary (N = 201, 55%); c. Are familiar with advanced ICTs, understand their significance, and often use them for learning (N = 109, 30%); d. Experts in ICTs, have much knowledge, experience, and skills in using them for learning (N = 16, 5%). Chi-square analysis indicated no statistically significant differences in the distribution of participants' gender ($\chi^2 = 7.32$, $p = 0.08$) or age ($\chi^2 = 3.95$, $p = 0.27$) by ICT groups. The distribution of males/females for each ICT group was: 9/28, 25/176, 8/101, 2/14 for groups a, b, c, and d, respectively. The distribution of younger/older students for each ICT group was: 20/17, 134/67, 78/31, 10/6 for groups a, b, c, and d, respectively.

Our analysis included two steps. First, we examined correlations between the mean item scores of the FTL scale (and subscales) and the *ICT expertise* ranks. Here, we expected to find positive correlations between the two measures. Second, guided by the literature (Hattie & Cooksey, 1984) we divided the students into two distinct groups: ICT enthusiasts (N = 125, 34%) - those with ranks of 3 or 4 on the *ICT expertise* measure; and ICT abstainers (N = 238, 66%) – those with ranks of 1 or 2.

Independent samples *t*-test compared the mean item scores of the FTL scale and subscales of each group. Here we expected to find statistically significant differences between the ICT enthusiasts and abstainers as to their inclination to think flexibly.

2.4.2. Stage 4: Results

A series of Spearman rank-order correlations were conducted in order to determine the relationships between the learners' ICT expertise and their scores on the FTL scale and subscales. A two-tailed test indicated statistically significant positive relationships for the FTL scale $r_s(363) = 0.36$, $p < 0.01$; and each subscale: *learning technologies acceptance* $r_s(363) = 0.44$, $p < 0.010$; *open-mindedness in learning* $r_s(363) = 0.12$, $p = 0.030$; and *adapting to new learning situations* $r_s(363) = 0.29$, $p < 0.010$.

Findings also indicated that ICT enthusiasts maintained statistically significant higher means on the FTL scale, compared to the ICT abstainers ($t(361) = 5.75$, $p = 0.000$). Not surprisingly, the *learning technologies acceptance* indicated the largest difference between the two groups ($t(361) = 7.30$, $p = 0.000$); compared to the *adapting to new learning situations* and *open-mindedness in learning* subscales ($t(361) = 4.76$, $p = 0.000$; $t(361) = 2.30$, $p = 0.020$, respectively). Fig. 2 presents a comparison between ICT enthusiasts and abstainers on the FTL scale and three subscales.

Our results support the known-groups validity of the flexible thinking in learning scale by indicating significant differences between groups that are expected to be different on this measured attribute. The ICT enthusiasts who tend to adjust quickly to new learning technologies and easily adopt innovations, indicated higher scores on the FTL scale; whereas the ICT abstainers, who are less inclined to adjust to changes, indicated low scores. This suggests that the FTL scale is a good differentiating tool.

2.5. Stage 5: Determining FTL's stability across populations and time

The purpose of this stage was to assess the FTL scale's reliability over a variety of conditions. First we examined the FTL scale's stability across populations, a significant process for assessing a scale's generalizability (Cook & Campbell, 1979). Given that the scale was generated to account for individual's dispositional inclination to flexible thinking in learning, we expected mean scores to be stable across demographic differences, such as learning path, gender, or age. In addition, since the FTL scale indicates individual's general disposition toward flexible thinking, it was expected to be stable over repeated measurements, as long as no intentional interventions were applied. The test-retest approach applied in this study is one of the most commonly used techniques for stability over time (Drost, 2011).

2.5.1. Stage 5: Method

This stage included two hundred and twenty-five participants. They were recruited by sending an online message to students who were enrolled to several graduate and undergraduate courses in two universities. Participation was voluntary with no extra credit or compensation. To assess stability over populations (Cook & Campbell, 1979), the FTL scale was administered among students from two different higher education institutions: a technology university (N = 75) and a teacher college institution (N = 150). A third (33%) majored in science and technology and 67% majored in humanities; 83% were women and 17% men; 63% were 18-to-25 years old and 37% above 26; 84% were undergraduate students and 16% were graduates. We applied, a univariate analysis of variance, expecting to find no significant effects with relation to participants' learning path (science and technology vs. humanistic), gender (female vs. male), or age (undergraduate vs. graduates). To assess stability over time (Drost, 2011), the FTL scale was administered twice: at the beginning and the end of one semester.

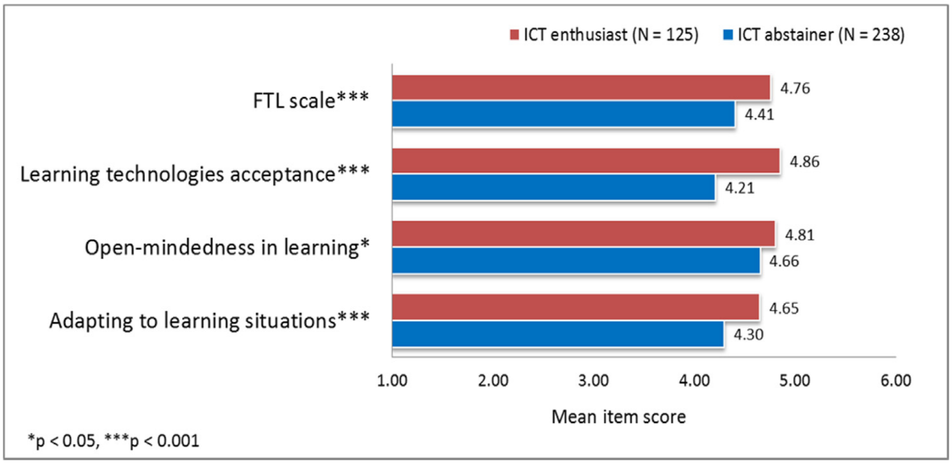


Fig. 2. ICT enthusiasts vs. abstainers on the FTL scale and subscales.

We applied a series of Pearson's correlations and paired samples *t*-tests, expecting to find positive relationships between the test-retest measurements and no significant differences between mean scores.

2.5.2. Stage 5: Results

In order to examine stability across population, we applied a series of multivariate analysis of variance, in which the dependent variables were the FTL scale and subscales and the independent factors were: learning path (science and technology vs. humanistic), gender (female vs. male), or Age (younger vs. older than 25). Table 6 presents the mean scores and standard deviations for each independent factor.

Table 6 shows no main effects for learning path, gender, or age. This suggests that the FTL scale and subscales' mean scores are stable across demographic differences, and therefore can be generalized (Cook & Campbell, 1979).

Consequently, in order to examine stability over time, we used Pearson's correlations to examine the relationships between the FTL scale and subscales scores on the test and retest measurements. In addition, paired samples *t*-tests were calculated (Table 7).

Table 7 shows significant positive correlations between the FTL scale and subscale scores test and retest. In addition, the differences in mean scores between the two measurements were statistically insignificant, except for the *Open-mindedness in learning*. However, since Partial Eta Squared test indicated a small effect size ($\eta_p^2 = 0.02$); the differences for the *Open-mindedness in learning* were considered as minor. Overall, our findings indicated that the FTL's scale was stable across populations and over time.

2.6. Stage 6: Determining FTL's concurrent validity

This stage was conducted to go beyond self-reported survey, by triangulating the data collected via the FTL scale with data that indicate actual practice (Oreg, 2003). The purpose of this stage was to assess relationships between individuals' scores on the FTL scale and their involvement in learning via a new and unfamiliar learning method. The new approach was inspired by the 'scientific activity' model, in which learners are active participants in the process of knowledge construction (NRC, 2012b; Osborne, 2014). Accordingly, participants experience a shift from lecture-based instruction to active learning, while emphasizing the exploration of new venues, creation of new contents, and providing and receiving feedback (Barak, 2016).

2.6.1. Stage 6: Method

This stage included fifty-four science and engineering students who voluntary participated in the study, in return for credit toward the fulfillment of course requirements. Gender distribution was 53% women, 47% men, and the mean age was 29 years (SD = 9.5). Throughout a 14-week semester, participants were involved in learning science by designing inquiry-based experiments, developing learning games, generating digital mind-maps, and producing short online videos. All the learning outcomes were created and managed via cloud-based technologies. No papers were exchanged between the students and the teaching team, adhering to the idea of a paperless curriculum (Barak, 2016; Barak & Ziv, 2013).

At the end of the semester, participants filled out the FTL scale and answered the following open question: During the course, you experienced new learning methods and technologies. Provide examples for: a. expressing openness to new experiences, people, or ideas; b. considering different perspectives; c. adapting to changes during your learning process. The participants' answers were rated according to the number of practical examples, ranging from no example (0 point) to four practical examples (4 points), as presented in Table 8.

2.6.2. Stage 6: Results

A series of Spearman rank-order correlations were conducted in order to determine the relationships between individuals' scores on the FTL scale and the practical examples for flexible thinking in learning. Findings indicated statistically significant positive relationships for the FTL scale $r_s(54) = 0.71$, $p < 0.01$; and each subscale: *learning technologies acceptance* $r_s(54) = 0.60$, $p < 0.01$; *open-mindedness in learning* $r_s(54) = 0.56$, $p = 0.030$; and *adapting to new learning situations* $r_s(54) = 0.69$, $p < 0.01$. Given that the participants were introduced to a new instructional approach, it is not surprising that we found a high positive correlations between the number of practical examples for flexible thinking in learning and the 'adapting to new learning situations' subscale.

Table 7
FTL scale's stability over time (N = 225).

	Time 1		Time 2		r	t(224)
	M	SD	M	SD		
1. FTL scale	4.56	0.59	4.53	0.61	0.68***	1.00
2. Learning technologies acceptance	4.43	0.95	4.43	0.90	0.66***	−0.15
3. Open-mindedness in learning	4.79	0.61	4.70	0.61	0.53***	2.57*
4. Adapting to new learning situations	4.41	0.71	4.42	0.71	0.60***	−0.13

*p < 0.05, ***p < 0.001.

Table 8
Examples for participants' applied flexible thinking in learning and their ratings.

Applying flexible thinking in learning	Ratings
As we were working on the collaborative documents, we had to show open-mindedness, as each of us had different ideas and opinions … (1 pt.) While preparing the mind-map, I was able to perceive things through the eyes of other team members. S.A. for example had a very particular order in her writing and I had to learn to see things from her point of view so that we can complete the task together. (1 pt.). When we designed the experiment we tried to be flexible. We tried to find an interesting experiment. (1 pt.) Adapting to the group was relatively easy and we consolidated ideas more and more as time went on. (1 pt.)	4 points
During the course, I had to learn how to use a new video software, I had to improvise and learn how it works (1 pt.)… At the beginning, I did not understand it because it was new to me. I had to overcome my inclination to see learning as a process of learning facts (1 pt.). We developed short games and videos and I reached the understanding that learning can be done out of the classroom walls (1 pt.).	3 points
Designing an inquiry-based experiment as a method of learning involved seeing the same concept in different perspective (1 pt.).	1 point

For further analysis, we compared between two groups of participants, according to their practical examples for applying flexible thinking in learning: those who provided no example or only one ($N = 19$) vs. those who provided two or more examples ($N = 35$). A Mann-Whitney test indicated statistically significant higher FTL means for participants who practically experienced flexible thinking in learning than their counterparts ($Mdn = 35.44$; $Mdn = 12.87$, respectively), $U = 54.50$, $p = 0.000$, $r = 0.68$. This result provides initial support for the concurrent validity of the FTL Scale, as triangulated with actual practice of undergraduates who experienced new learning methods and technologies.

3. Summary and discussion

Flexibility of thought is significant for living, working, and learning in our rapidly changing world (OECD, 2013; P21, 2009). Flexible thinkers are thought of as individuals who are open to new experiences and easily generate new ideas (McComb et al., 2007; Spiro et al., 2007). They adapt easily to varied roles and responsibilities, and work effectively in a climate of ambiguity and changing priorities (Bransford et al., 2000; P21, 2009). It is assumed that individuals who are open to new experience are less likely to be threatened by changes and are more likely to adopt new learning environments and technologies (Legris et al., 2003). However, in order to substantiate this assumption, there is a need for a valid and reliable questionnaire.

In light of the aforesaid, this study was set to generate a valid and reliable instrument for measuring individual's dispositional inclination to think flexibly in contemporary learning. Literature maintains that in order to generate a new conceptual framework and a measurement tool, researchers should first identify and define the construct of interest (Lawshe, 1975; Oreg, 2003). Following this notion and guided by previous studies, we identified three main factors that may indicate a learners' inclination to think flexibly: open-mindedness to others' ideas (DeYoung et al., 2005; Spiro et al., 2007), adapting to changes in learning situations (Barak & Ziv, 2013; OECD, 2013; Ployhart & Bliese, 2006), and acceptance of new or changing technologies (Barak, 2016; Edmunds et al., 2012; P21, 2009). Accordingly, *flexible thinking in learning* was conceptualize as a higher order thinking skill, comprised of open-mindedness as fundamental to the ability to adapt to changes in learning situations and to accept new or changing technologies.

The *Flexible Thinking in Learning (FTL)* questionnaire (Appendix A) was developed and validated in a six-stage analysis process. It's content validity was assured by experts in instructional science and its construct validity (i.e. theoretical framework) was reinforced via exploratory and confirmatory factor analysis (Cronbach & Meehl, 1955; Little, 2013), presenting a good fit model to the empirical data (Hu & Bentler, 1999). The structural equation modeling indicated *open-mindedness in learning* as a good predictor to both *learning technologies acceptance* and *adapting to new learning situations*. Our model provided evidence to support the assumption that individuals with a high inclination to be open-minded will most likely try new learning technologies and easily adapt to new ways of learning. In addition, our model suggests that a student's capability to adapt to new learning situations is predicted by both open-mindedness and willingness to use new learning technologies. These results provide a quantitative evidence for the important relations between the three components of flexible thinking in learning, as implied in previous studies (e.g. McComb et al., 2007; Spiro et al., 2007; Whitbourne, 1986).

The FTL questionnaire's discriminant validity was examined with relation to another validated measure (Messick, 1989). In this study, we used the resistance to change tool as an opposite scale since it is recognized as the quality opposite to acceptance, openness, and adaptability (Oreg, 2003). As expected, both scales and subscales yielded significant negative, yet moderate, correlations. Following these results, the known-groups validity analysis was conducted, examining differences between people with distinct expertise (Hattie & Cooksey, 1984; Heimberg & Holaway, 2007). Technology expertise was selected as an indicator since literature on 21st century skills associated flexible thinking with individual's inclination to use advanced ICTs (Edmunds et al., 2012; NRC, 2012a; 2012b). As expected, the ICT enthusiasts who tend to easily adopt new and advanced technologies indicated higher scores on the FTL scale; whereas the ICT abstainers, who are less inclined to use new technologies, indicated low FTL scores. Our results are supported by Devaraj et al. (2008) who maintained that individuals who are open to new experiences are also likely to be less threatened by the change implied in adopting new technologies.

In the last two stages, we examined the FTL questionnaire's stability over populations and time and triangulated data with actual practice. Our results indicated no main effect for learning path, gender, or age, which may suggest generalizability of results (Cook & Campbell, 1979). In addition, our results indicated no main effect for time, except for the open-mindedness subscale with a small size effect. This suggests that the FTL's scale can be stable over time, as long as no intentional interventions were applied. These results were reinforce by the sixth stage results, which provided support for the concurrent validity of the FTL questionnaire, as triangulated with actual practice of undergraduates who experienced new learning methods and technologies.

4. Conclusion, implications, and limitations

The FTL questionnaire was designed to serve as both a research instrument and a self-assessment tool. It may assist in the evaluation of learners' dispositional inclination to think flexibly or assist in explaining individual differences regarding the utilization of new learning methods or new technologies. Learners can use the FTL questionnaire as a reflective tool, raising awareness to their own strengths and weaknesses. Researchers can use it for examining the degree to which pedagogical interventions may affect learners' flexible thinking. Future research tied to FTL can address questions, such as: Whether and how can flexible thinking in learning be enhanced? Does flexible thinking depend on the learning contents or context? What are the relationships between flexible thinking and collaborative learning? The study of these important questions may promote the growing body of knowledge on learning in an era of rapid changes and reforms.

Whilst the validity and reliability of the FTL questionnaire were established through a rigorous six-stage study, limitations should be noted as well as recommendations for further research. The FTL scale was assessed by measuring ratings of undergraduate students who were enrolled in a variety of education and teaching diploma courses. We specifically targeted this population since the FTL scale was designed to examine flexible thinking in the process of learning. However, this led to a high percentage of female respondents. Although our population is in line with the female/male ratio in undergraduate education programs (AACTE, 2013), for wider generalizability, the FTL questionnaire should be examined in other learning situations and educational contexts. This may include learners from diverse age groups, academic backgrounds, ethnicities, and nationalities. Therefore, although our study indicated promising results for the FTL scale's validity and reliability, further examination should be conducted to meet the growing concern about reproducibility of social and cognitive studies (Open Science Collaboration, 2015).

Appendix A. Flexible thinking in learning (FTL) questionnaire

	Strongly agree	Agree	Somewhat disagree	Somewhat disagree	Disagree	Strongly disagree
Learning technology acceptance (TA)						
1. I adjust quickly to new learning technologies						
2. I adjust easily to technological changes as software updates						
3. I am open to updates in new technological tools that can help me learn						
4. I use various technological tools for learning and frequently change between them.						
5. I like to experience new learning technologies						
Open-mindedness in learning (OM)						
6. When learning, I listen to various opinions even if they contradict my opinion						
7. Even when I am convinced I am right, I listen to other learner's opinions						
8. In a learning process, I am open to feedback and criticism						
9. When learning, I tend to consider various possibilities						
10. When learning, I observe things from different perspectives						
11. For deep learning, I tend to examine diverse viewpoints						
12. It is important that different viewpoints will be expressed in the learning process						
Adapting to new learning situations (AL)						
13. I adjust myself to changes in learning conditions without difficulty						
14. I adjust easily when ways of learning change						
15. I do not have trouble getting used to new learning situation						
16. I adjust to different learning situations						
17. I am open to changes in my ways of learning even if it requires effort and work						

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