Learning styles in Engineering- an argument for re-consideration

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Structured abstract

CONTEXT
Concepts of learning styles are intuitive theories that have had an enduring popularity. Since major reports by Coffield et al. (2004b) and Pashler et al. (2008) the credibility of learning styles has diminished and learning styles are now being presented as a "neuromyth" by the OECD. Despite these strong arguments educationists continue to use learning styles to justify decisions in curriculum design. Who is right, the researchers or the educationalists?

PURPOSE OR GOAL
This paper argues that further learning style research is merited for Engineering Education researchers.

APPROACH
The approach taken in this paper involves a review of research literature from the fields of Neuroimaging and Learning Disabilities to find research that can contribute to the debate on learning styles in Engineering Education.

ACTUAL OR ANTICIPATED OUTCOMES
The literature shows that there is a little evidence that matching curriculum to individual learning styles significantly improves collective learning outcomes.

The fact that there are so many different theories shows that this field of research is currently fragmented and not grounded.

Recent literature from the field of Neuroimaging indicates that people do process information differently. Combining this with an understanding of learning disabilities from the field of Learning Disabilities strengthens the argument that learning styles is not a "neuromyth" and that it may still have relevance, especially to Engineering Education.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY
There is a scarcity of evidence to support attempting to match curriculum to the learning styles of all students. However the application of learning styles still has the potential to improve learning for **some** students in Engineering Education. Further research, especially more longitudinal and mixed methodology research, in this field is recommended.

KEYWORDS
Learning Styles, Autism, Dyslexia

Introduction

Concepts of learning styles are intuitive theories that have had an enduring popularity (Stahl 1999). They assume that individuals process information differently and thus will learn differently (Litzinger et al. 2007). Some learning styles theories predict that when there is a mismatch between a student's learning style and the teaching then the learning of the student suffers (Felder & Silverman 1988). However there is a wide variety of learning style models (Coffield et al. 2004b) and evidence that matching teaching to a student's learning style preferences improves learning outcomes is hard to find (Pashler et al. 2008). Consequently fewer researchers are persisting in learning style research (Peterson, Rayner & Armstrong 2009). This paper will consider recent research in neuroimaging, which shows that students with different learning style preferences do process information differently, and research on learning disabilities, which indicates that catering for the specific learning characteristics of students with certain disabilities can be beneficial, to argue that further learning style research is merited and that attempts to label learning styles as a "neuromyth" may be premature.

Methodology

The research for this paper was a literature search, the foundation of which was based on references the author has collected over the last three years of investigating learning styles. The literature search used the databases EBSCOhost, Gale Cengage Academic OneFile, PubMed Central and Google Scholar. Terms such as "neuroimaging learning styles", "autism aetiology", "dyslexia evidence based interventions", etc. were used to identify recent literature that related to this field. Journal articles returned by these searches were read for relevance to the research question. Issues of journals such as Dyslexia, Annals of Dyslexia, Autism, Research into Autism Spectrum Disorders, Molecular Autism, etc. over the last 3 years were reviewed for recent research that might contribute to this research question. References used in these papers reviewed were accessed where appropriate.

A Wide variety of models

There is a wide range of learning style theories. In order to clearly understand the differences in these theories I will provide an overview of two of the models which have had widespread coverage in recent research literature. These models will be referred to later when constructing my argument on the relevance of learning style research.

VAKT

One of the most enduring theories is the Visual/Auditory/Kinaesthetic/Tactile (VAKT) model. The genesis of this model can be traced back to the early 1920s when Grace Fernald and Helen Keller published a paper that outlined a kinaesthetic approach to help children with a reading disability (Fernald & Keller 1921). It is noteworthy that one of the authors of this paper, which promoted the use of kinaesthetic learning, is the celebrated Helen Keller who was both blind and deaf ('HELEN KELLER' 1888).

A current VAKT model is attributed to Frederic Vester (Looss 2001) who suggests that there are four different types of learner: The Auditive learner, who learns best by speaking and listening; The Visual learner, who learns best by watching; The Haptic learner, who learns best by touching and feeling, and; The Intellectual learner, who learns best by thinking.

Index of learning styles

Another learning style model was developed by Richard Felder and Linda Silverman (1988), called the Index of Learning Styles (ILS). This learning style theory was developed specifically for use in Engineering Education. It is a theory that is widely used is engineering and IT education research.

The ILS is a more complex model than VAKT. It borrows key elements from other well-known learning style models. It currently has 4 different dimensions that relate to how students obtain and process information (there used to be 5 different dimensions, but the authors deleted one scale as they came to the conclusion that only one end of that dimension was appropriate for teaching (Felder & Silverman 1988)). A learner can be placed anywhere along each dimension between the opposing poles, thus according to the authors there are 2^4 different learning styles in this model (See Table 1).

There is a *Perception* dimension, borrowed from Carl Jung and the Myer-Briggs Type Indicator (MBTI) (Felder & Silverman 1988, p.676). A learner can range from being someone that perceives through sensing and observing to individuals who use intuition, speculation and hunches to perceive.

There is an *Input* dimension, which shares similarities with elements of the VAKT model. A learner can range from being a visual learner who tends to better remember things seen, as in diagrams and demonstrations to being a verbal learner where they better remember what they have heard, said or read.

The *Processing* dimension is shared with David Kolb's *Learning Style Inventory (Felder & Silverman 1988, p. 675)* and is closely related to the MBTI extrovert/introvert dimension. Active learners learn better by experimenting, trying things out and working in groups. At the other end of the Processing dimension are reflective learners who learn better when they can reflect and theorise what they learn. Reflective learners tend to learn better when working by themselves.

The *Understanding* dimension is similar to the Dunn and Dunn model's analytic/global dimension (Dunn & Griggs 2000). In this dimension learners are either towards the Sequential pole, where they like to master information in the order in which it is presented or Global where students learn making quantised intuitive leaps rather than steady incremental progress.

Table 1 - Dimensions of Felder's ILS

DIMENSION	POLES	
Perception	*Sensing*	*Intuiting*
Input	*Visual*	*Verbal/Auditory*
Processing	*Active*	*Reflective*
Understanding	*Sequential*	*Global*

Other models

On top of the models described and referred to above, there are many other models that vary on the dimensions they include. Some models see learning styles as relatively fixed and constitutionally based, whereas others see them merely as variations in learning approaches that can change with time or environment (Coffield et al. 2004b, p. 19). Daniel Willingham treats learning styles as being separate to abilities. He gives the example of those playing sport who approach the game differently, some with a conservative style, others with a more risk taking style (Britt 2009).

There are many different learning style models. In fact one report identified over 71 different learning style models (Coffield et al. 2004b).

Problems with learning style models

The fact that there is a wide variety of models with a *"bedlam of contradictory claims"* (Reynolds in Coffield, Moseley et al. 2004) indicates that there are significant problems in the field of learning style research.

Lack of theoretical grounding and coherence

Researchers generally do not develop new models unless they find existing models to be inadequate. However, as the number of models grew, it should have been clear to those who developed newer models that their models should be better grounded in learning theories that are supported by research. The report by Coffield et al. (2004b) counted over 30 different learning style dimensions that had been used in the different models and observed that learning style theories suffer from *"a lack of consensual or coherent theory, poor psychometric test properties, self-promoting and affirming researchers, over commercialization of tests, and poorly established applications and links to practice"* (Coffield et al. 2004b).

There is an absence of agreement of key terms in research

The report by Coffield et al. (2004b) also noted the proliferation of terms which were often used interchangeably by some researchers and differently by others. In response to the criticism of learning style theories that arose from this report, Peterson, Rayner and Armstrong (2009) surveyed researchers who were persistent in learning styles research. They found significant disparity in how different researchers defined key terms in this field (such as *cognitive style* and *learning style*). It is little wonder that this field of research is often criticised for the *"confusion and contradiction with style definitions"* (Armstrong & Rayner, 2002; Rayner, 2007c).

If the same term means drastically different things to different researchers, then how do their peers collate their research?

The study by Peterson, Rayner and Armstrong (2009) observed that the majority of researchers treated *cognitive styles* as being stable and innate, and *learning styles* as being more variable and environmentally dependant. However 27.3% of researchers that participated in this phase of the study felt that: *Learning styles are individual differences in the way a person processes information (i.e., their cognitive style) which determines their typical or preferred response (cognitive and behavioural) in a learning context. A person's learning style is relatively stable.* (Peterson, Rayner & Armstrong 2009, p. 520). In other words a significant section of the learning style research community treat the terms *cognitive style* and *learning style* very similarly.

The overarching assumption in learning style research is that "*individuals vary in the way they process information, and thus will vary in the way they learn"* (Litzinger et al. 2007) and dialogue between researchers should at least have this assumption in common. Whether this variation in learning is due to underlying cognitive infrastructure or due to factors that are more behavioural and transient is a secondary concern.

For the remainder of this paper and for the sake of clarity in analysis the following definition of learning styles will be used: *Learning Styles are the characteristics of learners that cause the variability in the way they learn*. This will include those variables that are relatively fixed, such as those that cause dyslexia, autism, etc.

Whether it is better to use the term *cognitive style* or *learning style* will be left to later research. The term *learning style* will be used as a synonym throughout this paper, even when the research cited originally used other terms.

Absence of evidence

In 1999 (Stahl) observed an "*utter failure to find that assessing children's learning styles and matching to instructional methods has any effect on their learning".* In the Coffield et al. (2004a) report the authors stated: *There is not a single theory of cognitive or of learning style which is supported by evidence from longitudinal studies of stylistic similarities and differences in twins* (Coffield et al. 2004a, p.8). Later a review of learning styles literature commissioned by *Psychological Science in the Public Interest* (Pashler et al. 2008) concluded that *"there is no adequate evidence base to justify incorporating learning styles* *assessments into general educational practice"*. To Pashler et al. (2008) evidence consists of *"finding that a given student's learning is enhanced by instruction that is tailored in some way to that student's learning style"*.

To be lacking sufficient evidence to support a theory for over a decade of research is indeed damning. Arising from this prolonged absence of evidence the Organisation for Economic Co-operation and Development's (OECD) Centre for Educational Research and Innovation (CERI) has declared the VAKT learning style model to be a *"Neuromyth"* (Rimmele 2013). This declaration has been picked up and re-iterated in many internet blogs . This author has identified at least 15 which discuss learning styles being a neuromyth. Many of these web pages fail to distinguish between the VAKT model identified by the OECD as a neuromyth and other learning style models which have been demonstrated to have elements of validity (Coffield et al. 2004b, p.56; Litzinger et al. 2007; Livesay & Dee 2005).

Despite this strong argument against learning styles theory some researchers persist in studying learning styles (Peterson, Rayner & Armstrong 2009).

Insights into learning styles arising from neuroimaging

Either unaware of the criticism aimed at learning style theory or persistent in their belief in the validity of learning style theory some researchers are applying neuroimaging techniques to seek evidence of learning styles in learners. One tool that has been used extensively in this field is Functional Magnetic Resonance Imaging (fMRI). fMRI can detect changes in blood flow to different locations in the brain (Dimoka 2012). If research subjects process information differently, then one would expect that different regions of the brain being used to process the same task would show up as being active.

Kraemer, Rosenberg and Thompson-Schill (2009), Miller et al. (2012) and Eldar, Cohen and Niv (2013) have recently used fMRI to investigate learning styles.

Kraemer, Rosenberg and Thompson-Schill (2009) used a revised version of the Visualizer-Verbalizer Questionnaire (VVQ) and subtests of the Wechsler Adult Intelligence Scale (WAIS) to determine whether a subject had a visualising or verbalising learning style. By scanning subjects while they performed word-based and picture-based matching tasks they were able to observe that those subjects who were identified as visualisers had a higher probability for greater activity in the fusiform gyrus (a region of the brain recognised for its role in visual processing) when performing the word matching task. Similarly those subjects who were identified as verbalisers had a higher probability of greater activity in the supramarginal gyrus (a region of the brain used to process phonological input – e.g. spoken words) when performing the picture matching task. In other words subjects tended to process pictures and words in a manner that was more likely to align with their learning style preference.

Similarly Miller et al. (2012) also used the VVQ, with a number of other related questionnaires to determine whether their subjects had a visualising or verbalising learning style. While being scanned with fMRI subjects were asked to remember a lists of high-imageablity words or a list of low-imageability words. They observed that learning style accounted for a statistically significant portion of the variance they observed in their results.

A paper published by Eldar, Cohen and Niv (2013) used the ILS developed by Felder and Silverman (1988) to determine where subjects fell on the Perception dimension, i.e. whether participants were *Sensing* in their perception or *Intuiting*. Another difference to this research was that the authors' primary objective was not to locate the regions of the brain being used to process the task. Their primary focus was on observing the effects of learning style mismatch on neural gain. The authors describe neural gain: "*as an amplifier of neural communication: when gain is increased, excited neurons become even more active and inhibited neurons become even less active*" (Eldar, Cohen & Niv 2013, p.5). The authors observed that when participant's learning style aligns with the task then there is an increase in neural gain.

This last paper is particularly interesting as it suggests evidence that learning may be enhanced when learning styles on this dimension are matched. If Hebbian learning requires the firing of neurons (Lafond & Tremblay 2010; Shaw & McEachern 2013) then an increase in neuronal gain might be considered evidence of boosted learning.

So these papers from the field of Neuroimaging provide evidence that there are indeed individual differences in learning style both in the Visual/Verbal dimension and the Sensing/Intuiting dimension. These papers also demonstrate validity in the apparatus used to determine the subject's learning style preferences. While they do not provide sufficient evidence to support the claim that matching teaching to student learning styles improves learning outcomes, the results of these papers suggest that further investigation may be warranted.

Interaction of learning disabilities and learning styles

After reviewing the existing research literature on learning styles Pashler et al. (2008) found no evidence that would justify using learning styles in teaching. However in their report they argue that there is a difference between a learner's *style* and their *ability.*
After arguing that there is *"no credible evidence that learning styles exist"*, in their article "The Myth of Learning Styles" Riener and Willingham (2010) state: *"some students have specific learning disabilities, and these affect their learning in specific ways. For example, there is considerable research on dyslexia and the strategies for addressing it. These strategies of course differ from those appropriate for those students on the autistic spectrum or those with hearing difficulties. In each of these cases, a specific difference in the student calls for individual diagnosis and attention"* (Riener & Willingham 2010). In a separate paper Willingham argues that dyslexia is due to disorders of auditory processing in the brain (Willingham & Lloyd 2007).

This underscores what was said above about the importance of researchers having alignment with key terms in learning style research. If learning style research is primarily about differences in how students learn, then shouldn't abilities and disabilities also be considered?

One thing that both the Willingham and Pashler groups may not have adequately considered is the nature of learning disabilities. Learning disabilities are generally not a binary condition where you either have the disability or not. They occur on a spectrum (Matson & Neal 2009) as they are often not due to a single deficit (Pennington et al. 2012). Diagnosis of some learning difficulties are based on both the number and strength of certain characteristics, with a cut-off being set to determine who is recognised as having the learning disability (Bishop & Seltzer 2012). Different diagnostic tools are used in different regions (Thomson 2010). Inevitably this will mean that two individuals, both experiencing a similar magnitude of disability will be diagnosed differently depending on which side of the threshold they are assessed to or which apparatus they are assessed with.

In order to better elucidate this examples of Dyslexia and Autism Spectrum Condition (ASC) as raised by Willingham and Lloyd (2007) will be explored to see if current understanding of these disorders can contribute to the argument on whether further research into learning styles is warranted.

Dyslexia

Dyslexia is a disorder where those who suffer from it have a deficit in encoding printed words (Pennington et al. 2012). Traditionally it was fairly safe for university educators to assume that students who suffered from learning disabilities such as dyslexia would have been filtered out by the system and never have made it to university. However early diagnosis and effective educational intervention have resulted in an increase in dyslexic students entering higher education (Callens, Tops & Brysbaert 2012). Thus engineering educators will find a higher incidence of dyslexia amongst their students than in the past.

Twin studies suggest that genetics is a major contributor to the incidence of Dyslexia (Kovas & Plomin 2007), in other words the disorder is stable and innate and not just due to behavioural factors. Even though the contribution of genetics to the incidence of dyslexia is acknowledged, the aetiology of dyslexia is not fully understood. While it is generally accepted that dyslexia is at least partially due to a phonological deficit (Hakkaart-van Roijen 2011), Georgiou (2012) identified that children with dyslexia were more likely to have visual processing deficits than auditory processing deficits. Complementarily Lallier (2013) and Moore (2007) found that a significant minority of children's reading deficiencies are due to a deficiency in audiological processing. These wide ranging observations of the cause of dyslexia underscore that it is not due to a single deficit. The result of this research suggest that while one student's dyslexia may arise from a deficit in audiological processing, another's may be due to a deficit in visual processing. Diagnosis of dyslexia is complex as its cause is not due to a single factor and the difficulties that are associated with dyslexia occur on a continuum (Fälth et al. 2013; Thomson 2010).

Successful interventions for dyslexia are multi-sensory i.e. involving *"simultaneous linking of visual, auditory and kinesthetic information to enhance memory and learning"* (Thomson 2010). From the early 1920's when Fernald and Keller (1921) published an intervention for dyslexia a core component of the intervention was kinaesthetic learning. In one example, Pearce, Graham and Paterson (2010) have shown that by using an intervention with strong kinaesthetic and pictographic components, learning outcomes have significantly improved for students who traditionally have language and learning delays. For those who have dyslexia arising from auditory processing deficiencies Moore (2007) has demonstrated successful interventions using "*auditory learning".* In this research auditory learning involved the playing of computer games where the participant had to respond to different phonemes (i.e. the smallest components of spoken language that allow us to construct and differentiate words). Odegard et al. (2008) have contributed to the understanding of the complexity of dyslexia by using fMRI studies to show that many students who do not respond to phonological interventions process phoneme mapping tasks differently to those students who did improve.

Autism Spectrum Condition

Asperger's syndrome, low functioning autism and high-functioning autism are some examples of the development disorders grouped within the Autism Spectrum Condition (ASC) (Kanai et al. 2012). ASC's are a range of development disorders that share three core diagnostic domains: social impairments; difficulties in communication; and, repetitive behaviours and rigid interests (Cicchetti 2006; Dworzynski et al. 2009).

Cognitively, individuals with an ASC have deficits in: *executive function*, which results in a adjusting more slowly to new situations (Cicchetti 2006); *working memory,* which results in smaller amounts of transitory information being remembered; and, *heightened sensitivity to sensory information/weak central coherence,* which results in the difficulty of filtering out superfluous detail (Chen, Rodgers & McConachie 2009). One consequence of this is that ASC individuals retain detail *"at the expense of global configuration and contextualised meaning (Happe 1999)*. Happe (1999) and Chen, Rodgers and McConachie (2009) all argue that this may be a specific cognitive style.

The educational impact of having these cognitive deficits mean that ASC students will have lower efficiency in learning new information that is presented as a stream or in a transitory mode. As such ASC students would not be what Felder and Silverman (1988) call *verbal* learners. Jones et al. (2009), along with others they cite, have observed that poor reading comprehension is associated with ASC symptoms. This means that ASC students would learn more efficiently with static visual information sources. Consequently it is no surprise that using visual teaching aids is identified as being an evidence based intervention (Odom et al. 2012) and strongly recommended when teaching ASC students (Ministry of Education 2000, Odom, 2012 #236). Even though this affinity to visual aids would lead some to classify ASC students as *visual* learners, such a classification must consider that dynamic visual aids, such as videos or demonstrations, may still not improve the efficiency of learning if the pace of information presented is too fast for the ASC student.

ASC's are highly heritable. In recent twin studies the estimated concordance (i.e. where both twins have the disorder) is estimated to be between 88-95% for identical twins, and only 31% for fraternal twins. It has a genetic aetiology that alters how the brain develops (Baron-Cohen 2006). Environment and behaviour are not recognised as significant contributors to the prevalence of the disorder. Having three diagnostic domains means that ASC's are not a result of a single deficit. Some of the cognitive deficits of autism, such as deficits in executive function, have been shown to be present in milder forms in non-autistic parents and siblings (Nydén et al. 2011, Ronald, 2011 #156, Dworzynski, 2009 #155). This suggests that it may be possible to inherit different autistic traits from different parents.

Not all characteristics of an ASC are necessarily a disorder. In one well used psychometric test, the *embedded figures test* the performance of ASC individuals tends to be superior (Chen, Rodgers & McConachie 2009). This, combined with the enhanced ability to hold repetitive, rigid and detailed interests means that individuals with these ASC associated traits can be well suited to careers that require these characteristics (Baron-Cohen 2006; Happe 1999).

Not only are individuals with ASC traits well suited to some careers, it seems that they may well be attracted to certain careers. This has specific relevance to engineering as Baron-Cohen et al. (1997) found that autistic children were more than twice as likely to have a father working as an engineer than non-autistic children. This finding was confirmed by Jarrold and Routh (1998) who also identified high rates other systemising occupations such as science and accountancy. As such engineering educators could assume a greater concentration of autistic traits amongst their students than educators from some other disciplines.

Discussion

The field of learning styles has many significant issues it must address, and researchers are well justified in being cynical. However when experienced educators continue to find appeal in learning styles, this should suggest to researchers that here is a phenomenon that is worthy of continued investigation.

Despite claims that learning styles are a neuromyth (Rimmele 2013) evidence from recent neuroimaging studies suggest that some learning style models may be accurately describing the differences in how individuals process information (Eldar, Cohen & Niv 2013); (Miller et al. 2012); and, (Kraemer, Rosenberg & Thompson-Schill 2009).

Research into the learning disabilities dyslexia and autism spectrum conditions suggest these conditions have parallels to some dimensions in both the VAKT and ILS models. This research also demonstrates sufficient evidence to warrant the continued tailoring of curriculum to meet the learning needs of students with these conditions.

As a major aim of learning styles is to provide curriculum tailored to achieve optimal learning for individuals, all causes of student variation should be included in the research. In this context optimal learning means reaching final competence with the most efficient use of time and effort (Son & Sethi 2006).

Research into to learning disabilities also shows us that at times curriculum may need to be tailored to strengthen a learning weakness rather than matching curriculum to a learning style strength. Thus if a student has a weakness in auditory processing, auditory learning may be needed to strengthen this weakness (Moore 2007).

Learning disabilities that would have once prevented a student from entering university are being mitigated through interventions that are proving successful. Many of these interventions bear a strong resemblance to dimensions identified in a number of learning style models. Educators can expect that amongst the cohort of students they teach many will have traits of these learning conditions and some will be towards the disability end of the spectrum. This may be more the case in engineering education where the systemising characteristics of the engineering profession may concentrate the frequency of autistic traits in the engineering student population. If this is the case then methods used in successful interventions for students with diagnosed ASC might be considered for inclusion in engineering curriculum.

Current research suggests that incorporating learning style models into university curriculum is not yet warranted, however further research into learning styles is warranted.

Insights arising from this paper suggest the following possible questions for future research: Is there a relationship between a student's learning style and where they are on a learning disability spectrum? Can student learning be improved if we tailor curriculum against their learning style preferences.

The caveat is that the field has had more than its share of poor research. Hence, research into learning styles needs to be better: better integrated with the broader cognitive sciences; more robust in its psychometric tests (Coffield et al. 2004b); and, more longitudinal and mixed methodology research (Peterson, Rayner & Armstrong 2009).

Conclusion

The field of learning styles research has many problems that must be addressed. Consequently there is insufficient evidence to warrant incorporating learning styles into existing curriculum. However evidence arising from recent neuroimaging suggest that some models may have accurately identified dimensions where students process information differently. Successful educational interventions in the areas of dyslexia and autism spectrum conditions have had a strong resemblance to dimensions in some learning style models. Consequently whether engineering education should incorporate some of these successful interventions raises itself as a potential research question.

Limitations

As this paper is a literature review no new primary data has been produced. I have cited the findings of many authors. Some of these findings have had detractors. Due to space limitation some of these arguments have been superficially presented, while others have not been presented. These should be considered when designing further research in this field. Some primary sources of citations have not been accessible. When this has occurred secondary sources have been used.

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