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# Future of Education and Skills 2030: Conceptual Learning Framework

## A Literature Summary for Research on the Transfer of Learning

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This **draft paper** was written by Ruth BENANDER from the University of Cincinnati, USA. This is a literature review on far and near transfer of knowledge, skills, attitudes and values. This paper describes the kind of knowledge / skills / attitudes and values that are identified / supported by research for "near-transfer" and "far transfer" (including the aspect of "vertical transfer / horizontal transfer") across different disciplines and between school and everyday life.

This is still a "working document".

For **ACTION**: participants are invited to **COMMENT** before 5 November 2018.

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# *Table of contents*

# Abstract

In this paper, we begin by providing an overview of definitions on far/near transfer and horizontal/vertical transfer and describe the kind of knowledge / skills / attitudes and values that are identified / supported by research for "near-transfer" and "far transfer" (including the aspect of “vertical transfer / horizontal transfer”) across different disciplines and between school and everyday life. The review and consensus of the research has suggested that the following elements support the transfer of learning:

- Teaching “big ideas” and supporting students to see conceptual links between differing contexts.
- Practice of skills with immediate feedback
- Application of skills and knowledge in ill-structured problem solving situations
- Opportunities to practice skills learned in school in the context of work
- Scaffolding learning activities to build up from specific skills to application of those skills in different environments
- Support from instructors/supervisors, an explicit expectation of transfer, and a value of transfer

# Definitions of Transfer

## Overview

Nokes (2009[1])) approaches the problem of transfer of knowledge from the point of view of cognitive science asserting, “A central goal of cognitive science is to develop a general theory of transfer to explain how people use and apply their prior knowledge to solve new problems.” In his review of the mechanisms of transfer, he notes that researchers have approached the problem of transfer from several theories of transfer. Salomon and Perkins (1989[2]) argue that “transfer of knowledge and skills” is not a single phenomenon, rather, it is complex, conditioned event in which how knowledge or skills are transferred is interrelated with what is being transferred by whom, when, and where. Koedinger, Ydelson, and Pavlik (2016[3]) provide an in-depth review of two contrasting views of transfer. In one view, transfer of knowledge occurs because a general intelligence, or faculty of mind, has been strengthened and allows for new thinking across all new contexts. In contrast, they offer stronger support for envisioning transfer through a view of knowledge as multiple cognitive procedures invoked for specific tasks.

Contemporary views of transfer of knowledge seem to agree that transfer is not a general quality of mind, but the complex interplay of different kinds of knowledge dependent on context, experience, and social interaction (Lave, 1988[4]) (Day and Goldstone, 2012[5]). These writers conclude by observing that the traditional view of transfer as a trait within the learner has evolved to recognise transfer as including the social elements, discussed by Tuomi-Gröhn (2007[6]) for example, and epistemological elements, as discussed in the literature on novice and expert learners, such as in Hinds, Patterson, and Jeffrey (2001[7]). Since students will need to apply what they learn new circumstances, it is important to conceive of transfer of knowledge with a recognition of the complex relationship of components involved in transfer.

## Vertical transfer of knowledge

Haskell (2001[8]) presents a taxonomy for types of transfer of learning, but cautions that the categories he presents are not mutually exclusive. Haskell defines vertical transfer as, “required whenever learning necessitates prerequisite skills” (2001, p. 32[8]). On the surface such transfer can be viewed as relatively clear. If a student learns to read and write in class, then the student will be able to respond to tasks that require reading and writing in other contexts. However, the cognitive tasks of a new situation may require different approaches to reading and writing. In a study of Texas primary school literacy education, teachers commented that students who could read and write still needed explicit instruction and practice in the specific realisations of these skills that were required for the state standardised tests (Davis and Wilson, 2015[9]).

There is also the interaction of the basic skills being transferred in a testing situation. Some skills may be vertically transferred and others may not. Kempert, Saalbach and Hardy (2011[10]) found that in mathematical testing, language proficiency in the language in which the test was administered was a stronger predictor of performance that mathematical proficiency. Sometimes a skill one would expect to transfer vertically, will not transfer. Baker, Park, and Baker (2012[11]) found that initial levels of literacy skills in one language for early grade primary school students in one language did not predict similar growth in skills for the students' second language.

It is possible that the way skills are acquired may influence how well they transfer vertically from one context to another. Grant, Gottardo and Geva (2011[12]) report that students who were learning two languages simultaneously outperformed students who had learned one language and then were sequentially learning another language.

### Horizontal transfer of knowledge

Horizontal transfer of knowledge is transferring knowledge across different settings or contexts at the same level of abstraction. Day and Goldstone (Day and Goldstone, 2012[13]), in an extensive review of types of transfer, note that horizontal transfer has repeatedly been shown to be effective when the surface similarities of a context are easily perceived by students. They also point out that when the similarities between previous learning and the new context are more abstract, they are not able to reliably transfer their previous knowledge to the new context. Gick and Holyoak (1980[14]) demonstrated that participants were not able to transfer knowledge from an example to an analogous problem unless they were reminded that the example could give them a clue for how to solve the problem. They note that for horizontal transfer to be successful, students need to be reminded that their previous knowledge can help them solve the problem. Brown, Kane, and Echols (1986[15]) found, in a reading study with pre-school students, that students who read a story and then were reminded of the structural elements after reading, were able to successfully suggest solutions to a new problem that was then presented to them.

### Far transfer of knowledge

Transferring knowledge to novel situations seems more difficult (Bransford, Brown and Cocking, 1999[16]) (Barnett and Ceci, 2002[17]). Seel (2012[18]) identifies this ability to transfer knowledge to more complex contexts as "far transfer". Mestre (2002[19])provides this definition of transfer: "We define transfer of learning (hereafter transfer) broadly to mean the ability to apply knowledge or procedures learned in one context to new contexts" (p. 3). Marini and Genereux (1995[20]) define transfer of learning as "prior knowledge affecting new learning or performance" (p. 2). Berieter (1995[21]) further complicates the notion of transfer by asserting that first there is the transfer principle of a student recognising that they are able to transfer knowledge and skills, and secondly, there is the problem of transferring to new contexts the disposition to approach new problems in an analytic or principled way. He argues that while knowledge and skills can transfer readily to new situations, it is more challenging to teach students to transfer conceptual orientations, such as scientific analysis or statistical problem solving to novel situations.

In a comprehensive review of the literature on transfer and learning, Day and Goldstone (2012[13]) note that while near transfer is easy, what is actually difficult about far transfer is recognising that transfer is possible in the new situation. A person must recognise structural or conceptual similarities in order to invoke previous knowledge to apply in the new context. Day and Goldstone warn, "The literature on similarity and transfer suggests that students may often fail to recognise the relevance of these ideas when they are confronted with analogous situations in the real word, particularly when the specific concrete details of those situations do not closely match those presented by teachers" (2012, p. 156[13]). Given the challenge of far transfer, Dixon (2012[22]) suggests that it is important for instructors to help students see the more abstract conceptual and structural similarities between previous knowledge and new situations so that what is perceived as vertical transfer can be perceived more like the easier horizontal transfer.

In the case of being able to transfer knowledge to novel contexts, bilingualism may help students in seeing deeper similarities in context. Calvo and Bialystok suggest that bilinguals outperform monolinguals on cognitive tasks that require executive functions, such as ignoring irrelevant information, task switching, and resolving conflict (2013[23]).

### Near transfer of knowledge

Near transfer of knowledge means solving problems with similar characteristics or carrying out some learned skills in real contexts resembling learning environments. In general, the research shows that near transfer is the most likely form of transfer to be successfully influenced by classroom instruction. It is possible that near transfer is affected by working memory ability. Nelwan and Kroesbergen (2017[24]) studied 9-12 year old children learning mathematics. These children had attention challenges and difficulties learning mathematics. The researchers found that, indeed, students who practiced with math training software were able to perform the problems better than students who did not train with the software, although the gains were small. McCarthy, Webb and Hancock (1995[25]) also found that 11 year old students who trained on verb recognition tasks with various forms of feedback were able to perform better on a post-test of the skills they practiced. The groups of students who received feedback on their practice outperformed students who did not receive feedback.

Hovic et al. (2013[26]) also worked with 10-12 year old students with attention disorders to study long-term near transfer by training working memory skills. After a 25 day training in practicing short term memory tasks, students showed general improvement in similar tasks after the training and in assessment eight months after the training program.

Kneppers, Elshout-Mohr, Boxtel, and Hout-Wolters (2007[27]) confirmed that near transfer is more likely to be supported by instruction than far transfer. In a study of 16-18 year old students learning economics topics, they found that students who applied conceptual information to a practical scenario were better able to address practical scenarios in a post-test than those who had just practiced linking economic concepts. Neither group performed well on a semi-far transfer post-test that asked the students to apply concepts in a new context.

# Transfer of Knowledge

## Epistemic Knowledge

Epistemic knowledge is knowing how to think like a professional in a particular discipline. A term relating to this view of thinking like a professional is "habits of mind". This term relates to how a member of a particular discipline creates, evaluates, and advances knowledge of the discipline (Harlen, 2010[28]). This manner of disciplinary thinking can be interpretive lens through which experts in the field understand and solve complex problems (Gurung and Hayne, 2009[29]).

Teaching "habits of mind" help students learn to think like experts in the field. The extensive literature in health sciences and education on novice vs. expert learning is useful in understanding how successful transfer can be and how skills and knowledge overlap (Meyer, 2004[30]) (Oliver and Butler, 2004[31]). Novices learn new problems using clear rules, so beginning students need clear, well-structured problems to solve when first learning the new knowledge. However, this rule based learning for well-structured problems does not help students when they encounter ill-structured problems in the more complicated work-world (Garfield, 2017[32]) (Green, Jones and Bean, 2015[33]). Green, Jones and Bean (2015[33])recommend scaffolding assignments to build from well-structured to ill-structured so that students can become confident in their skills and begin to move from being guided by rules to being guided by principles they adapt to new situations. They argue that novices do not have the expert "habits of mind" and need specific practice and support to learn these "habits of mind" through learning to apply the principles of the field.

It is difficult to transfer knowledge or skills if one does not have sufficient previous knowledge to build on. Brom, Bromová, Děchtěrenko, Buchtová, and Pergel (2014[34]) found that students who watched a three hour video of how to brew beer scored higher on a test of transfer of knowledge if they had strong previous knowledge, experience with learning from video, and a positive attitude about learning from video.

Fink (2003[35]) has noted that traditional lecturing has been demonstrated to have limited effectiveness in promoting the transfer of knowledge and skills, citing research as far back as 1968. He promotes "significant learning experiences" that are engaged and high energy, what is current referred to as "active learning" instead of extensive lecture, if the goal of a learning experience is transfer of knowledge and skills. Similarly, fourteen years later, Garfield (2017[32]) reiterates, "… research shows that it is not enough to instruct students about the correct rules and concepts in order for them to develop an integrated understanding to guide their reasoning." For students to be able to develop and transfer their reasoning skills, Garfield (2017[32])recommends case studies and authentic tasks as well as other applications of their skills rather than passive listening to what those skills are from their instructors.

## Procedural Knowledge

In the field of cognitive psychology, a distinction is drawn between procedural knowledge, how to do a task, in contrast to declarative knowledge, knowledge of facts. Nokes (2009[1]), in his research on mechanisms of transfer, suggested that declarative knowledge can inform procedural knowledge by facilitating inferences about what needs to be done in a novel situation. He calls this contribution of declarative knowledge to procedural knowledge in a novel task "knowledge compilation" (Nokes, 2009, p. 3[1]).

More recent research in knowledge systems suggests that procedural and declarative knowledge interact to create a strategy system for learners. Rittle-Johnson and Schneider (2014[36]) suggest that both what something is and how to use it combine synergistically to inform critical thinking to solve novel problems. As suggested by Nokes, a student creates both kinds of knowledge through experiential learning that allows for a rich environment promoting both kinds of knowledge, but a learning environment that focuses on only one form of knowledge may not provide a student will all the strategies he or she needs to be able to creatively respond to novel applications of that learning. Levin (2018[37]) presents a case study of a pre-algebra student who demonstrated use of iterative strategies to solve word problems by using declarative knowledge and procedural knowledge to inform each other and through iterative processes build on both types of knowledge to solve novel problems. Levin suggests that these two types of knowledge are not productively viewed as static or separate since they inform and build on each other in the critical thinking process.

In order for a student to apply previous knowledge in a novel context, he or she must learn in situations that promote and reinforce both knowing what something is *and* how to use it. The implication from both Nokes (2009[1]) and Levin (2018[37])is that it is harder for a student to solve novel problems if he or she has only be exposed to situations that emphasise one form of knowledge or the other. In the United States, the *Conceptual Frameworks for New Science Education Standards,* science education should include both knowledge and skill as "a collective enterprise and no longer characterised as separate entities" (Kelley, Capobianco and Kaluf, 2014, p. 522[38])

Consonant with the assertion that procedural knowledge and declarative knowledge function together to create a mutually informed understanding of novel contexts, the concept of "system thinking" suggests that instead of viewing phenomena as discrete parts, instead people understand phenomena as parts that are synthesised to function as a whole. Ackoff asserts that we are emerging from thinking of the world as made up of discrete parts to thinking of the world as interrelated systems (Kirby and Rosenhead, 2005[39]). Education may also be seen as moving from viewing a subject as a collection of facts to understanding a disciplines as interrelated systems. The challenge for education is to facilitate the both declarative and procedural knowledge for students to be able to understand the larger systems of the discipline.

Mobus (2018[40])defines systems thinking for the classroom as "[being able] to see how the systems are organised for purposes and how, if they fail to serve those purposes, they will not be able to persist as systems." Mobus believes that when students learn systems thinking, they build an expectation to see systems according to an abstract template for the patterns of a successful system. In other words, they are able to transfer the declarative knowledge of what a system is and the procedural knowledge of how to a system works, to recognise and understand the ill-defined systems of the real world. In a course for students with no previous experience with systems thinking, Mobus (2018[40]) found that through experimentation with a complex, real-world problem, students were able to use the principles of system thinking. Omari (2016[41]) similarly suggests, but without empirical data, that primary school children can also construct system thinking perspectives when presented with real-life organisational problems in their classrooms, such as how to improve lining up in class or organising class materials.

Design thinking, similar to system thinking, is also focused on problem solving for ill-defined problems, and while similarly embracing a holistic view of the problem, focuses on specific views. For example, design thinking is concerned with methods to solve the problem, if the solution actually works, what do the users need, contemporary social and cultural appropriateness of the solution, and the aesthetic appeal of the solution (Pourdehnad, Wexler and Wilson, 2011[42]). Pourdehnad, Wexler and Wilson suggest that involving the stakeholders of a system in designing the solution to a problem can lead to a better, more sustainable solution. Indeed, Omari's proposal of teaching system thinking to her primary school class through designing solutions to systems in the classroom is an excellent example how to implement this type of teaching and learning.

In empirical studies of teaching system thinking and design thinking in primary education, Kelley, Capobianco, and Kaluf (2014[38]) found that students in a primary school science classroom, who were asked to solve problems that were unfamiliar and ill-defined, were able to come up with multiple design solutions.

## Disciplinary Knowledge

The transfer of disciplinary knowledge for students in primary and secondary school is lacking. The concern for this type of transfer of knowledge is emphasised in university education where the conversation is focused cognitive and skills transfer of knowledge.

Transfer of disciplinary knowledge within a discipline can encompass epistemic transfer, learning to think in discipline specific ways, and cognitive transfer of specific key concepts. Meyer (2008[43])defines these key concepts as "threshold concepts" or, "... 'conceptual gateways' or 'portals' that must be negotiated to arrive at important new understandings."

Work in "threshold concepts" suggests that students need to learn these key concepts in order to have a discipline specific understanding of the phenomena they study. Talenquer (2014[44]) summarises the characteristics of threshold concepts as transformative, integrative, irreversibly understood, hard to understand, and specific to the discipline. There is overlap with the concept of "big ideas", which are at the heart of a discipline, explanatory, and hard to grasp. Talenquer suggests that threshold concepts enable students to think in discipline specific ways about the big ideas of the discipline. Anecdotally, Tanquer asserts that university undergraduates who learn threshold concepts in their lower level classes outperform their colleagues in traditional courses both in skills transfer and transfer of conceptual understanding.

## Interdisciplinary Knowledge

Interdisciplinary knowledge is also not as emphasised in primary and secondary school education research as it is in university education. In health sciences, there is a particular focus on interdisciplinary transfer of knowledge. Croen, Hamerman, and Goetzel (2001[45]) describe how having medical students and nurses collaborate in the care of geriatric patients increased their understanding of the different roles they had in patient care. Cooper, Carlisle, Gibbs and Watson (2001[46]) conducted a literature review concerning empirical evidence that interdisciplinary programs promote skills in health professionals. While they authors found that there were few empirical studies, they did find that, "Student health professionals were found to benefit from interdisciplinary education with outcome effects primarily relating to changes in knowledge, skills, attitudes and beliefs."

Ivanitskaya, Clark, Mongomery, and Primeau (2002) exemplify the more common type of evaluation of programs without empirical data described by Cooper et al. (2001[46]). In a review of their program, Ivaniskays et al. assert, "By focusing on an issue or core theme, interdisciplinary approaches encourage students to perceive the connections between seemingly unrelated domains, thereby facilitating a personalised process of organising knowledge" (p. 99). Hersham, Luna, and Light (2004[47]) do offer assessment of student reception of interdisciplinary learning in nanotechnology. In a study involving university undergraduates, they found that students who took the course in the new interdisciplinary curriculum scored, on average, a full grade higher than students who had taken the course in the traditional mode.

Noroozi, Teasley, Biemans, Weinberger, and Mulder (2013[48]) describe the components that help multidisciplinary teams work. They describe how such a team must establish a "transactional memory system" to combine the knowledge of the group to develop a shared awareness of the group's expertise. Communication is key to this social construction of knowledge, and the researchers suggest that specific scripts might help groups communicate more effectively. In their study, university students formed interdisciplinary groups to solve problems. Those with scripts shared more knowledge and created higher quality problem solving plans than control groups.

# Transfer of Skills

## Cognitive and Meta-cognitive Skills

As Salmon and Perkins (1989[2]) are supported by later research that transferring knowledge from one situation to a similar situation, or near transfer/lateral transfer, seems to be relatively easy, while transferring knowledge to novel situations, or far transfer/vertical transfer, seems more difficult (Barnett and Ceci, 2002[17]) (Bransford, Brown and Cocking, 1999[16]). In fact, what a student considers near or far transfer can depend on his or her individual perceptions or expectations of what is similar or novel. Transfer is not automatic, and in fact, lab studies have shown it is quite rare (Barnett and Ceci, 2002[17]) (DeCorte, 2003[49]).

Grieff et al. (2014[50]) emphasises how important it is for students to learn "domain-general" problem solving, which overlaps with "ill-structured" problem solving. The consensus seems to be that specific, rote skills are important for the beginners, but the role of the educator is to help the beginner begin to apply those skills in new, general, ill-defined situations so that they can learn to apply their knowledge and skills in different ways. DeKorver, Choi and Towns (2017[51]) assessed whether traditional instruction of the "Fusion Science Theater" format would help children grasp a science concepts. They found that students who learned a concept through the format of a play were able to effectively describe the concept in their own words after the dramatic presentation as well as show an increase in comprehension in the science concepts after the show compared to before the show.

Project-based learning is another highly engaging method of learning that helps students engage in problem solving towards the goal of completing a project. Lee and Tsai (2004[52]) worked with upper grade elementary school students in an online simulation of project based learning. They focused on how different thinking styles of groups influenced transfer of concepts and skills. First the instructors taught lessons in basic science concepts and skills. Then groups of students participated in project-based learning activities. The project groups were divided into different styles of interaction with the content: planning the project, executing the plan, judging performance, and a mixed group that involved all three interactions. Lee and Tsai (2004[52]) found that the group that involved all three types of interaction with the concepts and skills evidenced better near and far transfer of knowledge than the single focus thinking style groups.

A great deal of research has been conducted on the cognitive and meta-cognitive transfer between languages. Baker, Basaraba and Polanco (2016[53]) review the literature on student learning in bilingual education. They found that bilingual language instruction helped students perform better in reading skills in both languages, although they report that studies on writing skills in bilingual programs were few. In science bilingual study, results have been mixed. Ciechanowski (2014[54]) reported that students in a bilingual program increased in both language proficiency and content knowledge. However Martinez-Alvarez, Bannan, and Peters-Burton (2012[55]) found that students increased in reading proficiency but not in content knowledge. Keung and Ho (2009[56]) found that primary school children learning English and Chinese, where Chinese was the societal language, were able to transfer reading cognitive skills to support word recognition in both languages.

## Social and Emotional Skills

Tuomi-Gröhn and Engeström (2003[57]) assert that the individual cannot be viewed as the sole locus of transfer, and they identify situational contexts beyond the activity as situated transfer (participations across situations) and sociocultural transfer (interactions between people working on a task).

Lightner, Benander, & Kramer (2008[58]) looked at attitude for transfer from the perspective of faculty and student expectations. Anecdotally, students are more concerned about what a particular teacher wants on a given assignment. Sherman (1985[59]) suggests that they actively try to adapt to these idiosyncratic requirements. Thus, students may focus more on what they think the teacher wants, than on what kinds of thinking the assignment requires. Pressley et al. (1998[60]) found that students are very aware of factors that guide studying style. What students see as idiosyncratic requirements may actually be expectations of more general transfer that they do not understand.

Cooley, Burns, & Cumming (2016[61]) explored how student attitudes might relate to transfer. They found that university students who were skeptical of group work, undertook an outdoor education course that taught the value of group work through experiential learning. Attitudes towards group work improved, and students reported a strong intention to continue to use group work in the traditional university setting. Similarly, in workplace training, Grossman and Salas (2011[62]) find that cognitive ability, beliefs of self-efficacy, motivation, and perceived utility of the new skills are strongest in individuals who demonstrate transfer of skills in employment training. Govaerts, Kyndt, and Dochy (2018[63]) add that part of that positive attitude must also come from the instructor to support the students in valuing transfer of skills. They found that supporting supervisors to be good trainers influences employees to retain skills from training and continue to use them in the workplace. This support of the supervisors is effective as long as the supervisor responsible for the training remains involved with the employees. Without reinforcement of the value of transfer, employees and students, may perceive that the transfer is not valued and not bother to apply learned skills in new contexts.

## Physical and Practical Skills

Wardle (2007[64]) identifies three different areas of concern for understanding transfer of learning: tasks, individuals, and activities. Tasks are the skills that can be transferred, the individual must have the disposition to transfer those skills, and the activities are the actions where the individual can transfer those skills.

The literature on effective learning for transfer has emphasised practice of skills in "ill structured problems" (Bransford, Brown and Cocking, 1999[16]); (Ge and Land, 2003[65]); (Jonassen, 1997[66]). An "Ill structured problem" is one where the goals, actions, end state, and constraints are unclear and need to be established through a collaborative environment. When students practice skills they have previously learned in the context of an ill-structured problem, they are better able to transfer the new knowledge they acquire in the process to new problems. Ge & Land (2003[65]) suggest that students find solving ill-structured problems to be difficult, but when the experience is scaffolded through helpful prompts and guided peer interactions, they can be more successful in this more difficult transfer situation.

Zarei, & Rahimi (2014[67])found that students were best able to transfer specific language skills like vocabulary and rules of syntax from one context to another, as well as more general skills such as research skills, summarising and quoting from one course to another. Interestingly, sometimes transfer may not show up in the standardised testing environment. Corte, Verschaffel and Ven (2001[68])discuss how young students who learned reading strategies that included modeling of explicit skills along with group work were able to use those strategies in other reading situations even though their scores on a standardised test did not change. It is possible that the standardised test was a context in which the reading did not feel realistic.

Research in learning writing skills and rhetorical knowledge has also concerned many researchers. Robertson, Taczak, and Yancey (2012[69]) write extensively on this topic. In their perspective, transfer is a dynamic activity in which they invoke prior knowledge. They transfer knowledge in three ways: 1) using skills exactly as they learned them previously in the new context, 2) adapting the skills to the new context, and 3) creating new skills based on the previous knowledge when the previous two approaches fail. The failed direct transfer prompts students to create new ways of thinking about those skills. They find that reflective practice helps students become of aware of previous knowledge that they can transfer. They also recommend ePortfolios are practices that support students in reflecting on their learning and creating an expectation of transfer (Yancey, Robertson and Taczak, 2014[70]). Jarratt et al (2008[71]) also find that students learn skills, but they do not know they can transfer them unless they are prompted to remember what they know. Then they are able to transfer skills from one context to another.

Wardle (2007[64]) has also published a great deal of research on transfer and student writing. Wardle (2007[64]) writes that students may generalise writing skills in one course, but they still require context specific support for the expectations in other disciplines that require writing. General writing practices can be taught in one course, but they are practiced in discipline specific ways. Wardle suggests that "Writing across the Curriculum" and "Writing in the Disciplines" are the best ways for students to apply general principles in specific contexts. Wardle (2007[64]) further theorises that transfer, in the social context as defined by Tuomi-Gröhn (2007[6]), can be seen as "repurposing". In this vision of transfer, a student takes knowledge acquired in one context and reshapes it according to the new requirements of a different context. It is not so much transferring a skill, per se, it is creating a new skill based in a new context based on knowledge of the old skill learned in the old context.

The current research in the transfer of learning from simulations and virtual reality is promising due to the interactive quality of the learning and the opportunities to practice the skills with immediate feedback. Kron et al. (2017[72]) found that virtual reality training in communication skills for second year medical students resulted in students perceiving themselves to be better prepared to transfer what they learned to patient care than students who learned from watching a video training module. Students valued the immediate feedback of the VR and the interactive practice not afforded by the video training. Similarly, Abuzour, Lewis, and Tully (2018[73]) note that six months after a virtual reality lesson on how to take a patient's history, students were still able to demonstrate those skills. However, the authors note that continual practicing of the skill in a social context that the virtual reality lesson taught was key to sustaining the transfer of the skill. This finding supports the findings of Tuomi-Gröhn (2007[6]).

In computer simulation studies, transfer has also been found to be more likely than in more passive learning situations. Meier et al. (2008[74]) found that in a computer simulation program, presenting a well-structured technique within the context of an ill-structured problem helped students to be able to transfer the knowledge of how to do the well-structured technique in other situations. Liu and Su (2011[75]) noted similar success in an electrical wiring simulation. In their study, students who learned electrical wiring through a computer simulation lecture outperformed students who attended lectures and demonstrations. The students learning through the computer simulation had more opportunities to practice wiring than the students who only watched a demonstration.

# Transfer of Attitudes and Values

## Personal Attitudes and Values

Whereas research has begun to examine instructional methods (Case and Gunstone, 2002[76]) (DeCorte, 2003[49]), metacognitive processes (Pressley, Van Etten and Freebern, 1998[60]), and self-regulation (Winne and Hadwin, 1998[77]) (Zimmerman and Kitsantas, 2002[78]), little attention has been focused on the personal attitudinal components of transfer. Pea (1987[79]) discussed how attitudes influence transfer of learning, but did not measure attitudes or offer data to support this idea. In his research, he suggested that learner beliefs about the appropriate context for a skill will strongly influence its transfer. He used the example of Brazilian street children who could do calculations when they were selling merchandise on the street, but who were unable to do basic math when they got to school (p. 644). In later research, Liu and Su (2011[75]) and Cooley, Burns, and Cumming (2016[61]) present research that indicates if the learners are enjoying the learning process and valuing the lesson, they are more likely to transfer the knowledge and skills to a new context.

In research concerning learning science concepts, creating an engaging presentation seems to promote the ability to remember an abstract concept. DeKrover, Choi and Towns (2017[51]) and Kerby, DeKrover, Cantor, and Weiland (2016[80]) both document how science concepts presented through the structure of a play promote positive attitudes about science and a willingness to engage with the science concepts.

McCombs and Marzano (1990[81]) also showed that attitudes are key to self-regulation models affecting metacognition. Before a student can be metacognitively aware, he or she must believe that this is possible and desirable, thus setting up the possibility for transfer. However, there may also be a developmental aspect to a student's desire to engage in topics. Abell and DeBoer (2018) tested the learning progression for energy ideas from primary through secondary school students. They found that primary school students performed well in transferring what they had learned in school to performing on the test, while secondary school students performed below expectations.

Reflection is another attitude that can support transfer of learning. The structure of the learning environment that values reflection may help students better understand the opportunities for transfer. Resnick and Omanson (1987[82]) report, "A more reflective attitude on the part of students toward concrete and written manipulation may lead them to search for principles that connect the two types of transactions." They found that students had difficulty transferring mathematical principles of quantity from a lesson to a new context, but those who were able to reflect on what they did were more successful. Prawat (1989[83]) extensively reviews transfer strategies and observes that a student's orientation to mastering knowledge results in more self-aware learning, which helps them access knowledge they can use in a new situation. He comments, "How teachers characterise learning activities (i.e., the emphasis assigned to learning versus performance aspects of tasks) thus exerts a strong influence on students' motivational orientations" (Prawat, 1989, p. 34[83]).

## Local Attitudes and Values

Transfer of attitudes and values is evident in Homer and Kahle's (1988[84]) "value-attitude-behaviour model". They propose "a hierarchy of cognitions in which the influence theoretically flows from more abstract cognitions (i.e., values) to mid-range cognitions (i.e., attitudes) to specific behaviours." Milfont, Wagner, and Duckitt (2010[85]) extended this model to undergraduate university students in different countries using a questionnaire to see how attitudes of environmental threat would be perceived to affect values and behaviours. In a statistical analysis of responses, they found this to be true across the four cultures surveyed.

Schools and other institutions may wish to cultivate certain attitudes and values, which they would like students to embrace and transfer into behaviours. Velasco and Harder (2014[86]) describe a program called "The Youth as Agents of Behaviour Change" program of the International Federation of Red Cross and Red Crescent Societies. In this program, participants were to integrate sustainable development into their behaviour. The researchers report that in a five year assessment of the program, participants did change their behaviour. Velasco and Harder (2014[86]) identified the opportunity to practice their principles of sustainable development from their training in activities post-training as key to the success of the program.

There is also extensive research that shows teacher's attitudes about learning can be transferred to students thus influencing student behaviour. For example, McCross-Yergian and Krepps (2010[87]) found that negative teacher attitudes towards reading instruction strategies negatively affected student reading achievement. Blazar (2018[88]) studied 41 teachers of 9 and 10 year old students. He reports, "Findings indicate that teachers have causal effects on students' self-reported behavior in class, self-efficacy in math, and happiness in class. The magnitude of the teacher level variation on these outcomes is similar to or larger than effects on math test scores" (Blazar, 2018, p. 283[88]).

## Societal Attitudes and Values

It is important to consider the effects of social attitudes, values and expectations about learning and how these cultural perspectives may affect transfer. While Salomon and Perkins (1989[2]) and others characterise transfer as an interior, individualistic situation, Wardle (2007[64]) and Tuomi-Gröhn (2007[6]) characterise transfer as being socially conditioned. Catalo, Antheaume, and Ismail (2015[89]) found that a computer based simulation learning activity was conditioned by the cultural expectations of the students. Students from an educational system that emphasised rote learning had difficulty learning from computer based simulations that focused on research, interrogation of evidence, discussion, and synthesis. Chege and Njengere (2018[90]) also found that the cultural expectations of more traditional lecture based instruction was not at all conducive to transfer of knowledge or skills. Students who attended a generalised communication course that lectured on writing skills were not able to transfer the knowledge of rhetorical theory or the skills of research writing to other courses in the curriculum. Lightner, Benander, & Kramer (2008[58]) explain this problem of transfer as one of expectation. If the curriculum and pedagogy designers do not expect or value transfer, students will probably not transfer knowledge or skills.

## Human Attitudes and Values

In our increasingly interconnected world, students need to learn global competence and the appreciation for diversity that facilitates an equitable modern workplace. In 1968, Jane Elliot's experiential learning activity for third graders concerning racism was highly effective and touched off violent debate and polarised responses (Bloom, 2005[91]). This activity involves children being assigned random statuses that are arbitrarily designated as positive or negative, and then switching the statuses the next day to emphasise the arbitrary nature of the constructed stereotypes. Anecdotally, Elliot reports that students learn the lesson that racist attitudes are unkind, and she suggests that students transfer this attitude to their daily lives. It is a visceral and highly emotional activity that results in personalised negative emotions, which is why there is such debate about using this activity to teach young children about valuing diversity. Weiner and Wright (1973[92]) duplicated Elliot's experiential learning activity with children belonging to the majority group and report that two weeks after the activity, the children continued to hold less prejudiced beliefs when compared to children who had not participated in the activity.

Belousov (2016[93]) reports that this kind of experiential learning for members of privileged groups can also be effective for able bodied youth learning to value youth who have disabilities. Anecdotally, Belousove suggests that youth who participate in Paralympic games, participate as support teams for Paralympic athletes, and see elite Paralympic athletes as role models, learn value their peers who have disabilities and view them positively. The theoretical underpinnings of the effectiveness of these experiential learning activities is "contact theory" (Rapp and Freitag, 2015[94]). Rapp and Freitag assert, "We presume that associational networks exhibit a positive effect on tolerance as they allow for regular and enduring inter-group contacts in non-hierarchical situations" (2015, p. 1032[94]). These researchers conducted a survey of Swiss adults to try to measure how associational involvement relates to levels of tolerance for other groups. They found that individuals who participated in diverse groups reported higher levels of tolerance, as measured by the survey. Rapp and Freitag conclude, "In line with the key insights of contact theory, learning about diverse perspectives, ideas and lifestyles on a continuing basis is followed by the dismantling of prejudice and the promotion of tolerance" (2015, p. 1046[94]).

While experiential learning is effective, traditional classroom learning can also be effective in teaching attitudes of tolerance and value for diversity. In 2000, Modesto, California, instituted a required course, for 13-14 year old 9$^{th}$ graders, on religious diversity to promote tolerance, using the traditional read and discuss format of the classroom. While also touching off hot debate and close community scrutiny, Modesto school reported that, in surveys after the course which covered the major world religions, students were more likely to defend students whose religious beliefs were insulted. In a test of content knowledge, students scored significantly higher on knowledge about the religions they studied than they did before the course. Eleven years later, Lester and Roberts (2011[95]) evaluated the course using qualitative and quantitative measurements. They used surveys and interviews of teachers and students to assess the effects of the course. Lester and Roberts (2011[95]) report that four months after the course was over, students reported modestly more tolerate attitudes towards religious difference and a willingness to value rights for "least-liked" groups. Nevertheless, although the attitude of tolerance was documented to transfer to personal attitudes through self-report after the course, changes in behaviour are anecdotal.

# Big Ideas and the Transfer of Learning

## Big Ideas

The concept of teaching "big ideas" focuses on guiding concepts as a road to deeper learning and more effective transfer of knowledge and skills. Mitchell, Keast, Panizzon and Mitchell (2016[96]) describe organising teaching around a small number of guiding concepts that can serve to link various areas of study. Whiteley (2012[97])specifies that using "big ideas", instructors can help students identify recurring patterns that can be used to recognise conceptual similarities between previous knowledge and novel contexts.

In science education, OECD participating countries have endorsed teaching with "big ideas" programs seeking to integrate science, technology, engineering, and mathematics. Dixon (2012[22]) cites research supporting the assertion that focusing on guiding concepts support students being able to transfer skills from one context to another in a program for secondary school students. Students who applied key concepts across different contexts in engineering and science problem solving scored higher on a design problem solving test than those who did not. Lachapelle and Cunningham (2007[98]) report on "Engineering is Elementary", a program for primary school students that integrated engineering concepts with literacy and science topics. Students show an increase in general knowledge in science and engineering, and teachers have embraced the curriculum. However, Chalmers, Carter, Cooper, and Nason (2017[99])review the literature on the success of these integration efforts. They note that, in their review of programs, the discrete elements of STEM education are not sufficiently integrated under linking "big ideas". They propose a component framework for how to better integrate the concept of teaching with "big ideas" into the STEM curriculum (Chalmers et al., 2017[99]):

- within-discipline big ideas that have application in other disciplines (e.g. scale, ratio, proportion, energy)
- cross-discipline big ideas (e.g. variables, patterns, models, computational thinking, reasoning and argument, transformations)
- encompassing big ideas (e.g. conservation, systems, coding, relationships, change, representations).

Chalmers et al. (2017[99]) propose that this structure might help organise a curriculum as a way to address the problem of what to cut amid concerns of curriculum overload. However, they caution that the curriculum design must be systematic and iterative to be effective, rather than just adding more components to study, which would just intensify the curriculum overload.

Jaakkola and Veermans (2018[100]) offer an interesting caution for emphasising "big ideas" for younger students. In their research with 9-12 year old students, they found that using concrete representations took less time and resulted in better performance in transfer tasks. They hypothesised that there would be better transfer in the group for whom the representations became more abstract over time would transfer the information as a concept better than the students who learned with consistently concrete representations, but this was not the case.

They caution, "The results also question the effectiveness of concreteness fading in elementary school science education where the majority of students still operate in the stage of concrete operations" (Jaakkola and Veermans, 2018, p. 202[100]).

## Curriculum Overload

Curriculum overload has been identified as a problem as disciplines become more complex and specialised. In the literature on the transfer of knowledge, rote memorisation has been shown to not be conducive to transfer. However, it is also clear that students must have a store of knowledge to be able to complete problem solving.

The recommendations for curriculum design that promotes transfer suggests that students need to practice knowing and doing things as a holistic learning experience. They need to practice their knowledge and skills in both familiar and unfamiliar contexts with ill-defined, authentic problems to solve using both system and design thinking.

Research into the process of transfer shows how problematic it is to assume that transfer happens automatically. In fact, it does not, and there are many barriers in traditional teaching that may actually inhibit such transfer, barriers such as assessments that emphasise recall of discrete facts rather than application in various contexts, lack of practice applying concepts to different situations, or lack of interdisciplinary references in lectures. Institutional assessment practices that rely on standardised testing may inhibit transfer of learning. Dixon and Brown (2012[101])found that students who had participated in engineering problem solving activities performed better in connecting math and science concepts than those who had not participated in these active learning activities. They conclude by specifically targeting the problem of assessment in promoting teaching for transfer, "Until student assessment methods are modified to reflect less dependency on standardised tests, engineering and technology educators will garner will garner greater collaboration from math and science teachers when the latter can see that engineering and design-based curriculums do improve students' ability to solve standardised test problems" (Dixon and Brown, 2012, p. 15[101]). It is clearly not enough to change teaching strategies to promote transfer; assessment strategies must also change to acknowledge and support transfer of learning.

Researchers recommend teaching specifically with "transfer problems". A transfer problem is designed to explicitly allow a student to address a specific goal with information they have learned for class in an authentic, unfamiliar situation (e.g. (Robertson, 1990[102]), (Jonassen, 1997[66])). In pedagogy, this practice is embodied in Problem Based Learning (PBL). PBL was conceived in the 1960's for medical education, but has been adopted across the education spectrum (Barrows, 1996[103]). PBL involves ill-defined, real world problems solved in a group. Another related pedagogy is Project Based Learning (Boss, 2011[104]), which engage in real-world problem solving with technology. Both of these pedagogies involve some form of system thinking, design thinking, social problem solving, application of previous knowledge and skills, and motivation to find a real solution.

## Transfer Between School and Everyday Life

### School to Work

This importance of authenticity was noted by Grossman and Salas (2011[62]). Workplace training results in inconsistent transfer of skills from training to the worksite. Grossman and Salas (2011[62]) identify critical factors of trainee characteristics, training design, and work environment that influence the success of skills transfer. Trainees must feel they can accomplish the training and be supported in using the new skills. The training design must model the skills in a realistic application. Finally, the work environment must value the training by giving the trainee the opportunity to use the skills and follow up on the utility of the training.

As Wardle (2007[64]) notes, Tuomi-Gröhn (2007[6]) emphasised the social context of transfer. Transfer needs to be understood in the social system in which the individual acts. Transfer of knowledge from school to work is not just taking the skills from one context and using them in a new one. School and workplace collaborations need to take place so that in the context of the social collaboration, skills from school can be conceptualised and revised to fit the new situation in which they are used. Tuomi-Gröhn calls this "developmental transfer." It is instructive to understand the details of Tuomi-Gröhn's model of Developmental Transfer Mode (2007, p. 57[6]):

(a) A school, a student, and a workplace implement a shared developmental project with contributions from all participants;
(b) One or more theoretical concepts created during the learning process facilitate the understanding and reconstruction of the object of work in a new way;
(c) The learning process leads to implementation of the new concepts as tools or models of new activities;
(d) Expansion happens substantively, by constructing a more encompassing object and motive for the activity (substance expansion), and socially, by recruiting a growing number of participants in the transformation effort (social expansion)"

This inter-relationship of learning as a collaborative social act offers a practice guide to effective transfer for any program promoting the transfer of skills from instruction to practice at work. Abuzour, Lewis, and Tully (2018[73]) completed a study that supports this social foundation of transfer. They found that first, students must have sufficient basic knowledge to be able to transfer skills. Then, support from colleagues and adherence to guidelines helped students effectively transfer their skills from classroom to workplace.

# *References*


Abuzour, A., P. Lewis and M. Tully (2018), "Practice makes perfect: A systematic review of the expertise development of pharmacist and nurse independent prescribers in the United Kingdom", *Research in Social and Administrative Pharmacy*, Vol. 14/1, pp. 6-17, http://dx.doi.org/doi:10.1016/J.SAPHARM.2017.02.002. [73]

Baker, D., D. Basaraba and P. Polanco (2016), "Connecting the present to the past", *Review of Research in Education*, Vol. 40/1, pp. 821-883, http://dx.doi.org/10.3102/0091732x1666069. [53]

Baker, D., Y. Park and S. Baker (2012), "The reading performance of English learners in Grades 1-3: The role of initial status and growth on reading fluency in Spanish and English", *Reading and Writing*, Vol. 25, pp. 251-281, http://dx.doi.org/10.1007/s1145-010-9261-z. [11]

Barnett, S. and S. Ceci (2002), "When and where do we apply what we learn? A taxonomy for far transfer", *Psychological Bulletin*, Vol. 128/4, pp. 612-637. [17]

Barrows, H. (1996), "Problem-based learning in medicine and beyond: A brief overview", *New Directions for Teaching and Learning*, Vol. 68, pp. 3-12, http://dx.doi.org/10.1002/tl.37219966804. [103]

Belousov, L. (2016), "Paralympic sport as a vehicle for teaching tolerance to young people", *Procedia: Social and Behavioral Sciences*, Vol. 233, pp. 46-52. [93]

McKeough, A., J. Lupart and A. Marini (eds.) (1995), *A Dispositional View of Transfer*, Laurence Erlbaum Associates. [21]

Blazar, D. (2018), "Validating teacher effects on students' attitudes and behaviors: Evidence from random assignment of teachers to students", *Education Finance and Policy*, Vol. 13/3, pp. 281-309. [88]

Bloom, S. (2005), "Lesson of a Lifetime", *Smithsonian*, https://www.smithsonianmag.com/science-nature/lesson-of-a-lifetime-72754306/. [91]

Boss, S. (2011), "Project-based learning: a short history", *Edutopia*, https://www.edutopia.org/project-based-learning-history. [104]

Bransford, J., A. Brown and R. Cocking (1999), *How people learn: Brain, mind, experience, and school*, National Academy Press. [16]

Brom, C. et al. (2014), "Personalized messages in a brewery educational simulation: Is the personalization principle less robust than previously thought?", *Computers & Education*, Vol. 72, pp. 339-366, http://dx.doi.org/doi:10.1016/J.COMPEDU.2013.11.013. [34]

Brown, A., M. Kane and C. Echols (1986), "Preschool Children can Learn to Transfer: Learning to learn and learning from example", *Cognitive Psychology*, Vol. 1, pp. 103-121. [15]

Calvo, A. and E. Bialystok (2013), “Independent effects of bilingualism and socioeconomic status on language ability and executive functioning”, *Cognition*, Vol. 130, pp. 278-288, http://dx.doi.org/10.1016/j.cognition.2013.11.015. [23]

Case, J. and R. Gunstone (2002), “Metacognitive development as a shift in approach to learning: An in-depth study”, *Studies in Higher Education*, Vol. 27, pp. 459-470. [76]

Catalo, M., N. Antheaume and H. Ismail (2015), “Transferring methods to teach business administration from one cultural context to another”, *Future Business Journal*, Vol. 1/1-2, pp. 51-64, http://dx.doi.org/doi:10.1016/J.FBJ.2015.11.001. [89]

Chalmers, C. et al. (2017), “Implementing "Big Ideas" to Advance the Teaching and Learning of Science, Technology Engineering and Mathematics (STEM)”, *International Journal f Science and Mathematics Education*, Vol. 15/1, pp. 25-43. [99]

Chege, A. and D. Njengere (2018), “The State of Academic Writing in Kenyan Universities: Making a Case for Kenyan Universities to Re-conceptualize Their Approach to Teaching Academic Writing”, *The Journal for Research and Practice in College Teaching*, Vol. 3/1, pp. 10-46. [90]

Ciechanowski, K. (2014), “Weaving together science and English: An interconnected model of language development for emergent bilinguals”, *Bilingual Research*, Vol. 37, pp. 237-262, http://dx.doi.org/10.1080/15235882.2014.963737. [54]

Cooley, S., V. Burns and J. Cumming (2016), “Using Outdoor Adventure Education to Develop Students’ Groupwork Skills”, *Journal of Experiential Education*, Vol. 39/4, pp. 329-354, http://dx.doi.org/doi:10.1177/1053825916668899. [61]

Cooper, H. et al. (2001), “Developing an evidence base for interdisciplinary learning: A systematic review”, *Journal of Advanced Nursing*, Vol. 35/2, pp. 228-237. [46]

Corte, E., L. Verschaffel and A. Ven (2001), “Improving text comprehension strategies in upper primary school children: A design experiment”, *British Journal of Educational Psychology*, Vol. 71/4, pp. 531-559, http://dx.doi.org/doi:10.1348/000709901158668. [68]

Croen, L., D. Hamerman and R. Goetzel (2001), “Interdisciplinary training for medical and nursing students: Learning to collaborate in the caer of geriatric patients”, *Journal of American Geriatric Society*, Vol. 32/1, pp. 55-61. [45]

Davis, D. and A. Wilson (2015), “Practices and Commitments of Test-centric Literacy Instruction: Lessons from a testing transtion”, *Reading Research Quarterly*, Vol. 50/3, pp. 357-359, http://dx.doi.org/10.1002/RRQ.103. [9]

Day, S. and R. Goldstone (2012), “The Import of Knowledge Export: Connecting Findings and Theories of Transfer of Learning”, *Educational Psychologist*, Vol. 47/3, pp. 153-176, http://dx.doi.org/10.1080/00461520.2012.696438. [13]

Day, S. and R. Goldstone (2012), “The Import of Knowledge Export: Connecting Findings and Theories of Transfer of learning”, *Educational Psychologist*, Vol. 47/3, pp. 153-176. [5]

DeCorte, E. (2003), “Transfer as the productive use of acquired knowledge, skills, and motivations”, *Current Directions in Psychological Science*, Vol. 12/4, pp. 142-146. [49]

DeKorver, B., M. Choi and M. Towns (2017), “Exploration of a method to assess children's understanding of a phenomenon after viewing a demonstration show”, *Journal of Chemical Education*, Vol. 94/2, pp. 149-156, http://dx.doi.org/10.1021/ACS.JCHEMED.6B00506. [51]

Dixon, R. (2012), “Transfer of Learning: Connecting concepts during problem solving”, *Journal of Technology Education*, Vol. 24/1, pp. 2-17. [22]

Dixon, R. and R. Brown (2012), “Transfer of Learning: Connecting Concepts During Problem Solving”, *Journal of Technology Education*, Vol. 24/1, pp. 2-17. [101]

Fink, D. (2003), *Creating significant learning experiences: An integrated approach to designing college courses*, Jossey Bass/Wiley. [35]

Garfield, J. (2017), “The challenge of developing statistical reasoning”, *Journal of Statistics Education*, Vol. 10/3, p. n.p., http://www.amstat.org/publications/jse/v10n3/garfield.html. [32]

Ge, X. and S. Land (2003), “Scaffolding students’ problem-solving processes in an ill-structured task using question prompts and peer interactions”, *Educational Technology Research and Development*, Vol. 51/1, pp. 21-38, https://link.springer.com/content/pdf/10.1007%2FBF02504515.pdf. [65]

Gick, M. and K. Holyoak (1980), “Analogical Problem Solving”, *Cognitive Psychology*, Vol. 12, pp. 306-355. [14]

Govaerts, N., E. Kyndt and F. Dochy (2018), “The Influence of Specific Supervisor Support Types on Transfer of Training: Examining the Mediating Effect of Training Retention”, *Vocations and Learning*, Vol. 11/2, pp. 265-288, http://dx.doi.org/doi:10.1007/S12186-017-9190-Y. [63]

Grant, A., A. Gottardo and E. Geva (2011), “Reading in English as a first or second language: the case of Grade 3 Spanish, Portuguese, and English speakers.”, *Learning Disabilities Research and Practice*, Vol. 26, pp. 67-83, http://dx.doi.org/10.1111/j.1540-5826.2011.00327.x. [12]

Green, G., S. Jones and J. Bean (2015), “Teaching Real-World Applications of Business Statistics Using Communication to Scaffold Learning”, *Business and Professional Communication Quarterly*, Vol. 78/3, pp. 314-335, http://dx.doi.org/doi:10.1177/2329490615588908. [33]

Greiff, S. et al. (2014), “Domain-general problem solving skills and education in the 21st century”, *Educational Research Review*, Vol. 13, pp. 74-83, http://dx.doi.org/doi:10.1016/J.EDUREV.2014.10.002. [50]

Grossman and E. Salas (2011), “The transfer of training: what really matters”, *International Journal of Training and Development*, Vol. 15, pp. 103-12-, http://dx.doi.org/doi:10.1111/j.1468-2419.2011.00373.x. [62]

Gurung, N. and A. Hayne (2009), *Exploring Signature Pedagogies: Approaches to teaching disciplinary habits of mind*, Stylus Publishing. [29]

Harlen, W. (2010), *Principles and Big Ideas of science Education*, Association of Science Teachers. [28]

Harrison, D. et al. (2017), "Assessing the effectiveness of a hybrid-flipped model of learning on fluid mechanics instruction: overall course performance, homework, and far- and near-transfer of learning", *European Journal of Engineering Education*, Vol. 42/6, pp. 712-728, http://dx.doi.org/10.1080/03043797.2016.1218826. [113]

Haskell, E. (2001), *Transfer of Learning*, Academic Press. [8]

Herrmann, C., G. Abell and E. DeBoer (2018), "Investigating a learning progression for energy ideas from upper elementary through high school", *Journal of Research in Science Teachign*, Vol. 55/1, pp. 68-93, http://dx.doi.org/10.1002/TEA.21411. [111]

Hersham, M., M. Luna and G. Light (2004), "Implementation of interdisciplinary group learning nd peer assessment in a nanotechnology Engineering course", *Journa of Engineering Education*, Vol. 93/1, pp. 49-57. [47]

Hessler, K. and C. Cunningham (2007), "Engineering is Elementary: An engineering and technology curriculum for children", *American Society for Engineering Education*, https://www.researchgate.net/publication/242476335_Engineering_is_elementary_An_engineering_and_technology_curriculum_for_children. [109]

Hinds, P., M. Patterson and J. Pfeffer (2001), "Bothered by abstraction: The effect of expertise on knowledge transfer and subsequent novice performance", *Journal of Applied Psychology*, Vol. 86/6, pp. 1232-1243, http://dx.doi.org/10.1037/0021-9010.86.6.1232. [7]

Homer, P. and L. Kahle (1988), "A structural equation test of the vaue-attitude-behavior hierarchy", *Journal of Applied Social Psychology*, Vol. 54, pp. 638-646. [84]

Hovic, K. et al. (2013), "RCT of working memory training in ADHD: Long term near transfer effects", *Plos One*, Vol. 8/12, http://dx.doi.org/10.1371/journal/pone.0080561. [26]

Ivanitskaya, L. et al. (2001), "Interdisciplinary Learning: Process and Outcomes", *Innovative Higher Education*, Vol. 27/2, pp. 95-111, http://dx.doi.org/10.1023/A:1021105309984. [110]

Jaakkola, T. and K. Veermans (2018), "Exploring the effects of concreteness fading across grades in elementary school science education", *Instructional Science*, Vol. 46/2, pp. 185-207, http://dx.doi.org/10.1007/S11251-017-9428-Y. [100]

Jarratt, S. et al. (2008), "Pedagogical memory and the transferability of writing knowledge: an interview-based study of juniors and seniors at a research university", *WPA: Writing Program Administrators*, Vol. 33/1-2, pp. 46-73. [71]

Jonassen, D. (2000), "Toward a design theory of problem solving", *Educational Technology Research and Development*, Vol. 48/4, pp. 63-85. [108]

Jonassen, D. (1997), "Instructional design models for well-structured and III-structured problem-solving learning outcomes", *Educational Technology Research and Development*, Vol. 45/1, pp. 65-94. [66]

Kamouri, A., J. Kamouri and K. Smith (1986), "Training by exploration: facilitating the transfer of procedural knowledge through analogical reasoning", *International Journal of Man-achnie Studies*, Vol. 24/2, pp. 171-192, http://dx.doi.org/doi.org/10.1016/S0020-7373(86)80047-5. [106]

Kelley, T., B. Capobianco and K. Kaluf (2014), "Concurrent Think-Aloud Protocols to Assess Elementary Design Students", *International Journal of Technology and Design Education*, Vol. 25, pp. 521-540, http://dx.doi.org/10.1007/s10798-014-9291-y. [38]

Kempert, S., H. Saalback and I. Hardy (2011), "Cognitive benefits and costs of bilingualism in elementary school studnets: The case of mathematical word problems.", *Journal of Educational Psychology*, Vol. 103, pp. 547-561. [10]

Kerby, H. et al. (2016), "Demonstration show that promotes and assesses conceptual understanding using the structure of drama", *Journa of Chemical Education*, Vol. 93/4, pp. 613-618, http://dx.doi.org/10.1021/ACS.JCHEMED.5B00490. [80]

Keung, Y. and C. Ho (2009), "Transfer of reading-related cognitive skills in learning to read Chinese (L1) and English (L2) among Chinese elementary school children", *Contemporary Educational Psychology*, Vol. 34/2, pp. 103-112, http://dx.doi.org/10.1016/J.CEDPSYCH.2008.11.001. [56]

Kirby, M. and R. Rosenhead (2005), "IF ORS Operational Research Hall of Fame: Russel L. Ackoff", *International Transactions in Operational Research* , Vol. 12, pp. 129-134. [39]

Kneppers, L. et al. (2007), "Conceptual learning in relation to near and far transfer in the secondary school subject of economics", *European Journal of Psychology of Education*, Vol. 22/2, pp. 115-129. [27]

Koedinger, K., M. Yudelson and P. Pavlik (2016), "Testing Theories of Transfer Using Error Rate Leaning Curves", *Topics in Cognitivie Science*, Vol. 8/3, pp. 589-609. [3]

Kron, F. et al. (2017), "Using a computer simulation for teaching communication skills: A blinded multisite mixed methods randomized controlled trial", *Patient Education and Counseling*, Vol. 100/4, pp. 748-759, http://dx.doi.org/doi:10.1016/J.PEC.2016.10.024. [72]

Lachapelle, C. and C. Cunningham (2007), *Engineering is Elementary: Children's changing understanding of science and engineering*. [98]

Lave, J. (1988), *Cognition in Practice: mind, mathematics, and culture in everyday life*, Cambridge University Press. [4]

Lee, C. and R. Tsai (2004), "Internet project-based learning environment: The effects of thining styles on learning transfer", *Journal of Computer Assisted Learning*, Vol. 20/1, pp. 31-39, http://dx.doi.org/10.111/J.1365-2729.2004.00063.X. [52]

Lester, E. and P. Roberts (2011), "Learning about world religions in Modesto, California: The promise of teaching tolerance in public schools", *Politics and Religion*, pp. 1-25, http://dx.doi.org/10.1017/S1755048311000174. [95]

Levin, M. (2018), "conceptual and Procedural Knowledge During Strategy Construction: A complex knowleedge systems perspective", *Cognition and Instruction*, Vol. 36, http://dx.doi.org/10.1080/07370008.2018.1464003. [37]

Lightner, R., R. Benander and E. Kramer (2008), "Faculty and student attitudes about transfer of learning", *InSight: A Journal of Scholarly Teaching*, Vol. 3, pp. 58-66. [58]

Liu, H. and I. Su (2011), "Learning residential electrical wiring through computer simulation: The impact of computer based learning environments on student achievement and cognitive load", *British Journal of Educational Technology*, Vol. 42/4, pp. 598-607, http://dx.doi.org/doi:10.1111/J.1467-8535.2009.01047.X. [75]

McKeough, A., J. Lupart and A. Marini (eds.) (1995), *he challenge of teaching for transfer*, Lawrence Erlbaum Associates. [20]

Martinez-Alvarez, P., B. Bannan and E. Peters-Burton (2012), "Effect of strategy instruction on fourth-grade dual language learners' ability to monitor their comprehension of scientific texts", *Bilingual Research Journal*, Vol. 35/35, pp. 331-349, http://dx.doi.org/10.1080/15235882.2012.734005. [55]

McCarthy, M., J. Webb and T. Hancock (1995), "Form of feedback effects on verb learning and near transfer tasks by sixth graders", *Contemporary Educational Psychology*, Vol. 20/2, pp. 140-150. [25]

McCombs, B. and R. Marzano (1990), "Putting the self in selfregulated learning: The self as agent in integrating will and skill", *Educational Psychologist*, Vol. 25, pp. 51-69. [81]

McCross-Yergian, T. and L. Krepps (2010), "Do teacher attitudes impact literacy strategy implementation in content area classrooms?", *Journal of Instructional Pedagogies*, Vol. 4, pp. 1-18. [87]

McKeough, A., J. Lupart and Marini, A. (1995), *Teaching for transfer: Fostering generalizations in learning*, Erlbaum. [105]

Meier, D. et al. (2008), "Simulations with Elaborated Worked Example Modeling: Beneficial Effects on Schema Acquisition", *Journal of Science Education and Technology*, Vol. 17/3, pp. 262-273, http://dx.doi.org/doi:10.1007/S10956-008-9096-4. [74]

Mestre, J. (2002), "Transfer of learning: Issues and research agenda", *National Science Foundation Reports*, https://www.nsf.gov/pubs/2003/nsf03212/nsf03212.pdf (accessed on 17 July 2017). [19]

Meyer, H. (2004), "Novice and expert teachers' conceptions of learners' prior knowledge", *Science Education*, Vol. 88/6, pp. 970-983, http://dx.doi.org/doi:10.1002/SCE.20006. [30]

Meyer, J. (2008), *Threshold Concepts within the Disciplines*, Sense Publishers. [43]

Milfont, T., C. Wagner and J. Duckitt (2010), “A cross-cultural test of the value-attitude-behavior hierarchy”, *Journal of Applied Social Psychology*, Vol. 40/11, pp. 2791-2813, http://dx.doi.org/10.1111/j.1559-1816.2010.00681.x. [85]

Mitchell, I. et al. (2016), “Using 'Big Ideas' to Enhance Teaching and Student Learning”, *Teachers and Teaching*, pp. 1-15, http://dx.doi.org/10.1080/13540602.2016.1218328. [96]

Mobus, G. (2018), “Teaching Systems Thinking to General Education Students”, *Ecological Modeling*, Vol. 373, pp. 13-21, http://dx.doi.org/doi.org/10.1016/j.ecolmodel.2018.01.013. [40]

Nelwan, M. and E. Kroesbergern (2017), “Limited near and far transfer effects of Jungle Memory Working Memory Training on learning mathematics in children with attentional and mathematical difficulties”, *Frontiers in Pscychology*, Vol. 21, http://dx.doi.org/doi.org/10.3389/fpsyg.2016.01384. [24]

Nokes, T. (2009), “Mechanisms of Knowledge Transfer”, *Thinking and Reasoning*, Vol. 15/1, pp. 1-36, http://dx.doi.org/10.1080/13546780802490186. [1]

Noroozi, O. et al. (2013), “Facilitating learning in multidisciplinary group swth transactive CSCL scrips”, *International Journal of Computer-Supported Collaborative* , Vol. 8/2, pp. 189-223. [48]

Oliver, M. and J. Butler (2004), “Contextualising the trajectory of experience of expert, competent and novice nurses in making decisions and solving problems”, *Collegia*, Vol. 11/1, pp. 21-27, http://dx.doi.org/doi:10.1016/S1322-7696(08)60440-0. [31]

Omari, T. (2016), “How to Practice Systems Thinking in the Classroom”, *Teacher's Voice*, https://teacher-blog.education.com/how-to-practice-systems-thinking-in-the-classroom-9cbfa3dcd2cf. [41]

Pea, R. (1987), “Socializing the knowledge transfer problem”, *International Journal of Educational Research*, Vol. 11, pp. 639-663. [79]

Pourdehnad, J., E. Wexler and D. Wilson (2011), “System and Design Thinking: A conceptual framework for their integration”, *Organizational Synamics Working Papers*, Vol. 10, pp. 10-16, https://repository.upenn.edu/od_working_papers/10/. [42]

Prawat, R. (1989), “Promoting access to knowledge, strategy, and disposition in students: A research synthesis”, *Review of Educational Research*, Vol. 59/1, pp. 1-41, http://dx.doi.org/10.3102/00346543059001001. [83]

Hacker, D., J. Dunlosky and A. Graesser (eds.) (1998), *The metacognition of college studentship: A grounded theory approach*, Routledge Taylor and Francis Group. [60]

Rapp, C. and M. Freitag (2015), “Teaching Tolerance? Associational Diversity and Tolerance Formation”, *Political Studies*, Vol. 63, pp. 1031-1051, http://dx.doi.org/10.1111/1467-9248.12142. [94]

Glasner, R. (ed.) (1987), *Learning to understand arithmetc*, Erlbaum. [82]

Dowker, R. (ed.) (2014), *Developing conceptual and procedural knowledge of mathematics*, Oxford University Press. [36]

Robertson, L. et al. (2012), "Notes toward a theory of prior knowledge and its role in college compsers transfer of knowledge and practice", *Composition Forum*, Vol. 26, pp. 1-21, https://files.eric.ed.gov/fulltext/EJ985812.pdf. [69]

Robertson, W. (1990), "Detection of cognitive strucure with protocol data: Predicting performance on phystcs transfer problems", *Cognitive Science*, Vol. 14/1, pp. 253-280. [102]

Ross, B. (1984), "Reminding and their effects in learning a cognitive skill", *Cognitive Psychology*, Vol. 16/1, pp. 371-416. [107]

S., B. (2005), "Lesson of a Lifetime", *Smithsonian*, https://www.smithsonianmag.com/science-nature/lesson-of-a-lifetime-72754306/. [112]

Salomon, G. and D. Perkins (1989), "Rocky roads to transfer: Rethinking mechanisms of a neglected phenomenon", *Educational Psychologist*, Vol. 2/2, pp. 113-142. [2]

Seel, N. (2012), *Encyclopedia of the Sciences of Learning*, Springer. [18]

Sherman, T. (1985), "Learning improvement programs: A review of controllable influences", *The Journal of Higher Education*, Vol. 56/1, pp. 85-100. [59]

Talenquer, V. (2014), "Threshold concepts in chemistry: The critical role of implicit schemas", *Journal of Chemica Education*, Vol. 92, pp. 3-9, http://dx.doi.org/dx.doi.org/10.1021/ed500679k. [44]

Tuomi-Gröhn, T. (2007), "Developmental transfer as a goal of collaboration between school and work: A case study in the training of daycare interns", *Actio : An International Journal of Human Activity Theory*, Vol. 1, pp. 41-62. [6]

Tuomi-Gröhn, T. and Y. Engeström (2003), *Between School and Work: New Perspectives on Transfer and Boundary-Crossing*, Pergamon. [57]

Verlasco, I. and M. Harder (2014), "From attitude change to behavior change: Institutional mediators of education for sustainable development effectiveness", *Sustainability*, Vol. 6, pp. 6553-6575, http://dx.doi.org/10.3390/su6106553. [86]

Wardle, E. (2007), "Understanding transfer from FYC: Preliminary results of a longitudinal study", *Writing Program Administration*, Vol. 311-2, pp. 65-85. [64]

Weiner, M. and F. Wright (1973), "Effects of undergoing arbitrary discrimination upon subsequent attitudes toward a minority group", *Journal of Applied Psychology*, Vol. 3/1, pp. 94-102, http://dx.doi.org/doi.org/10.1111/j.1559-1816.1973.tb01298.x. [92]

Whiteley, M. (2012), "Big Ideas: A Close Llook at the Australian History Curriculum", *Agora*, Vol. 47/1, pp. 41-45. [97]

Hacker, D., J. Dunlosky and A. Graesser (eds.) (1998), *Studying as self-regulated learning*, Routledge Taylor and Francis Group. [77]

Yancey, K., L. Robertson and K. Taczak (2014), *Writing Across Contexts: Transfer, Composition, and Sites of Writing*, Utah State University Press. [70]

Zarei, G. and A. Rahimi (2014), "Learning Transfer in English for General Academic Purposes Writing", *SAGE Open*, Vol. January-March, pp. 1-12, http://dx.doi.org/doi.org/10.1177/2158244013518925. [67]

Zimmerman, B. and A. Kitsantas (2002), "Acquiring writing revision and self-regulatory skill through observation and emulation", *Journal of Educational Psychology*, Vol. 94, pp. 660-668. [78]