DUAL USE OF TIME: FRAMEWORK FOR UNDERSTANDING POSSIBILITIES AND PITFALLS

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ABSTRACT

A typical concern among faculty faced with requests for adding new and broader learning outcomes to existing degree programs, is that they might be forced to reduce their core disciplinary curriculum to make place for these new outcomes. The CDIO response to this is *dual use of time* – by means of integrated learning experiences, the same course slot can be used both to convey core disciplinary knowledge, professional skills, and societal relevance. However, empirical evidence for the effects of dual use of time seem to be limited. In this paper, we review empirical literature on various types of integrated learning, namely project-based learning, work-integrated learning, and content-language integrated learning. In addition, we discuss cognitive load theory and whether its findings have implications for such dual-purpose educational designs. Towards the end, we briefly discuss some frameworks, possibilities, and pitfalls for such integrated teaching.

KEYWORDS

Integrated learning, Dual use of time, Project-based learning, Conceptual load, Learning outcomes, Standards: 2, 3, 7, 11

INTRODUCTION

The employability of STEM candidates depends not only on strength in their core engineering discipline, but also on broader professional competencies such as communication skills, teamwork, and entrepreneurship (Forcael et al., 2021; Winberg et al., 2020), and the CDIO standards have recently been updated with sustainability and digitalization as key competencies for the future (Malmqvist et al., 2020). A typical concern among faculty faced with requests for adding new and broader learning outcomes to existing degree programs, is that they might be forced to reduce their core disciplinary curriculum to make place for these new outcomes. The tempting response to this from a CDIO perspective is to offer integrated learning experiences, so that the same course slot can be used to pursue several competencies in parallel, for instance core disciplinary knowledge, professional skills, and societal relevance. In CDIO literature, this approach is often called “dual use of time”, though it could be discussed whether this is the best term. Generally, the term “dual use of time” applies to performing several things in parallel – for instance that drivers should be able to perform other useful activities while waiting for their electric cars to charge (Philipsen et al., 2016). Early usage of the term in pedagogy also entails several activities in parallel, such as repeating key concepts while in the restroom (e.g., from notes posted on the wall), or listening to instructional cassette tapes while travelling (McCormick, 1988), thus learning something when you would otherwise be intellectually idle. The "dual use of time" proposed in the CDIO context is much more ambitious – rather than learning when otherwise idle, the goal is to learn multiple competencies in parallel, e.g., learning both fundamentals and professional skills (Bankel et al., 2003), thus reducing the need for dedicated courses (Armstrong et al., 2006). As stated in Edström et al. (2007), due to the cramped curricula of engineering study programs, "a curriculum has to make dual use of time and resources within disciplinary courses already available, capitalizing on the synergy of the simultaneous learning of skills and disciplinary outcomes." (p.79). However, unlike listening to instructional tapes while driving, which is clearly two different activities with no particular synergy, the CDIO approach is more often one integrated activity (e.g., students working in a team project about some engineering design task), hence it could be argued that the duality lies not in the use of time, but rather that the activity has *dual purpose,* e.g., to reach learning outcomes both in engineering design and in collaboration skills.

A key assumption for dual use of time from the CDIO viewpoint is that new learning outcomes that we want to add can be pursued in synergy with disciplinary learning outcomes – by use of appropriate learning methods such as project-based learning (Edström et al., 2007), so that students will reach the new outcomes (say, teamwork and collaboration skills) while still learning as much of the disciplinary topic (say, software design) as they did before. There have been many positive research results showing good learning effect from using such approaches, e.g., (Andrews & Clark, 2011; Kans & Gustafsson, 2012; Malmqvist et al., 2015), and Levine et al. (2008) show significant gains in 4 of 6 kinds of learning following the joint redesign of 6 courses in the same study program. Yet, the empirical evidence directly addressing the learning effects of dual use of time seems to be rather limited – at least a literature search for "dual use of time" + "empirical evidence" will give few relevant hits. This does not necessarily mean that evidence is absent, rather research could have been published using other terms than dual use of time, such as for instance integrated learning.

Our research questions for this paper are: (1) Along which different dimensions of competency can dual use of time be pursued? (2) What are the typical learning gains from dual use of time? (3) What – if any – are the most dangerous pitfalls of dual use of time?

This rest of this paper is structured as follows: In the next three sections, we look at three different types of learning that could be classified as "dual use of time" – or maybe better: dual purpose – namely Project-Based Learning (PjBL), Work-Integrated Learning (WIL) and Content and Language Integrated Learning (CLIL) – looking at empirical evidence for learning gains of these approaches. Next, we look at Cognitive Load Theory, which might in some situations pose an argument against dual use of time. In the final section, we outline a more general framework for considering potential gains and pitfalls of dual use of time.

PROJECT BASED LEARNING (PjBL)

Project-based learning (PjBL) is a natural starting point in this paper, as it has been identified as the dominant approach for integrative STEM learning (Mustafa et al., 2016), and CDIO-inspired redesign of study programs will likely have PjBL as a central component (Bolstad, 2021). A typical transformation might be from disciplinary courses previously taught through a series of lectures and small weekly exercises, to instead having students work with larger projects, individually or in teams (Leslie et al., 2021). From a perspective of outcomes, teachers used to a lecture-based approach and favoring content knowledge may fear that a change to projects will imply that some of the students' study time gets consumed by overhead related to the project collaboration, hence reducing their learning outcomes in terms of content knowledge. However, a review of empirical evaluations of PjBL courses by Ralph (2016) indicated that PjBL instead caused an increase in content knowledge – though it must be acknowledged that the number of reviewed studies was rather limited (14). Chen & Yang (2019), in a more comprehensive meta-analysis of studies directly comparing student achievement from PjBL vs. traditional lecture-based pedagogy found an average effect size of 0.71 in favor of PjBL, which can be described as a medium to large effect. The size of the effect differed somewhat between disciplines (larger in social sciences, smaller in STEM) and cultures (larger in Western countries, smaller in Asia), but is anyway a positive result for PjBL vs. a lecture-based approach. Looking at progression from junior to senior projects in study programs, (Lowe & Goldfinch, 2021) found a clear increase in breadth of knowledge drawn upon in the projects. However, there was no evidence of similar progression in the expected integrative capability of the students, suggesting a critical need for more work in that area.

Guo et al. (2020) reviewed publications assessing the outcomes of PjBL and found four main groups of outcomes being assessed: cognitive outcomes (knowledge, strategies), affective outcomes (perceptions of benefits and effectiveness of PjBL), behavioral outcomes (skills, engagement), and artefact outcomes (quality of the artefacts developed by the students).
An observed weakness, however, was that most of the reviewed studies evaluated outcomes largely by means of students' self-reported perceptions of learning outcomes, rather than more objective measures, such as pre- and post-tests measuring progress in content knowledge and skills from the PjBL course, or controlled comparisons of students who learnt a topic through PjBL versus students following a no-project approach

Paradoxically, there is more research documenting gains in content knowledge from team projects than there is evidence of gains in, e.g., collaboration skills. One reason could be that collaboration skill is a complex concept which is hard to measure (Scoular, 2021) and most teachers in project-based engineering courses are experts in their engineering discipline, not in collaboration, so teaching and assessment tends to focus on the engineering more than the collaboration as such, the latter assumed to be learnt by immersion. As indicated by Pazos et al. (2016) more scaffolding of the collaboration aspect could be needed to ensure students have substantial progress in this respect.

Hence, although PjBL can be an excellent way to achieve balanced learning of an engineering discipline together with employability skills such as communication and collaboration (Winberg et al., 2020), there is a potential tension between the teaching of content and skills, for instance concerning how much teacher and student effort goes into the scaffolding of each, and how much effort goes into the assessment of each.

WORK-INTEGRATED LEARNING (WIL)

Work-Integrated Learning (WIL) is a learning approach which includes placement of the student in an authentic work context. This does not mean that any placement or internship would qualify as WIL, rather the term WIL requires that there is a combination of formal education and the practical application of knowledge and skills in an authentic work-life context (Jackson, 2018). Hence, in a WIL unit within a university program, students typically have to deliver some kind of report to document their learning from the placement period. As described by Wood et al. (2020), in addition to WIL where the student is in the workplace, there may also be remote WIL where the student may interact with the authentic work task through the internet, and simulated WIL – which may be slightly less authentic, e.g., the university setting up work tasks which resemble as closely as possible authentic industry tasks. Remote and simulated WIL have received increased attention recently, as pandemic restrictions may have prevented students from physical presence in the workplace. Work-placement which does not have any formal framework may have great learning value for some students, but this will vary a lot from placement to placement. According to (Nagle et al., 2018), there is also a risk that such extra-curricular placements mainly lead to tacit knowledge which is hard to assess and hard to integrate with disciplinary knowledge. Hence, they suggest that WIL needs to be semi-formal, balancing explicit learning outcomes and assessment procedures with room for improvisation based on the nature of the placement and viable work-tasks.

Assessment in WIL is challenging as some outcomes may be unpredictable and differ from student to student. To address this challenge, Ferns & Zegwaard (2014) point to e-portfolios as a good way to enable students to document and reflect upon their learning in such. As argued by Leal-Rodriguez & Albort-Morant (2019), while there is plenty evidence for advantages of student-active learning methods, the evidence for gains in conceptual understanding resulting from experiential learning is scarce. However, in their study they found that company placement in a course in Management Skills affected positively the grade in a later exam focusing on mastery of theoretical concepts of management skills.

Dean & Sykes (2021) made an ethnographic study observing three students on placement. They found many positive learning experiences from WIL, but also found that it may have a lot of what they called “dead time” – where the students were unable to do much (or even learn much) because they were waiting for a workplace leader or mentor to allocate tasks to them or give feedback on performed tasks. There are several risks to WIL (Effeney, 2020), for all stakeholders involved. For the company it could be student misconduct in the workplace, for the university, it could be loss of reputations if placements fail. From a dual use of time perspective, poor learning outcomes for the student might be the most relevant risk to note. One specific cause might be if companies are using placement students mainly as cheap labor, caring less about learning outcomes (Mutereko & Wedekind, 2016). Also, there could be other causes, such as the abovementioned “dead time” or mismatch between job tasks and intended learning outcomes. However, based on studies of WIL in Australia, Jackson (2015) claims that cases when WIL was seen as less successful in learning outcomes could mostly be attributed to poor design of the WIL course unit, or of the study program at large, rather than an inherent problem with WIL as such. A typical challenge was students insufficiently prepared through previous courses regarding knowledge and skills they would need for their placement.

An interesting discussion by Björck & Johansson (2019) addresses the duality of theory vs. practice in WIL, criticizing the typical assumption that the learning of theory is what takes place in university, while practice in industry, industry thus representing “the real world” which academia is somehow not part of. They argue that rather than positing WIL as a way of bridging the divide between theory of practice, one should abandon this idea of duality altogether, instead viewing theory and practice as inseparable aspects of competency, as any theory is necessarily learnt in some social environment where it is practiced. Another interesting reflection by Fleming & Haigh (2017) is the danger that WIL is often designed with too much focus on preparing the students for the “now”, while they also need to be prepared for future jobs that do not yet exist.

CONTENT AND LANGUAGE INTEGRATED LEARNING (CLIL)

Content and language integrated learning (CLIL) is a pedagogical approach where a subject is taught in another language than the native language of the students (Dalton-Puffer, 2011), with the dual purpose of learning subject content (e.g., History) and a language other than the students' native one (e.g., English as a Foreign Language). Obviously, master level courses are taught in English in many countries although most of the students have a native language other than English. However, this as such would *not* qualify as CLIL – there needs to be the dual purpose of teaching subject content *and* the language through the same course. CLIL has received a lot of enthusiasm, and several studies have indicated gains compared to non-CLIL approaches with content instruction and language instruction separated in different courses – though evaluations have mainly focused on the language learning part (Dalton-Puffer, 2011), with much fewer studies identifying clear gains in content learning. Also, there may be cultural differences impacting the success, as CLIL has been more successful in southern Europe, e.g., Spain, less so in Sweden (Sylvén, 2013). CLIL has been used and researched mostly in secondary education, but there are also studies in tertiary education, for instance by Aguilar (2017) who found that engineering teachers tended to prefer English Medium Instruction (teaching a topic in English but focusing on the content without any dual purpose of teaching the language, too) rather than CLIL, because they identified as experts in the engineering topic, not in technical English.

In addition to the challenge that teachers do not identify as language teachers, they may also fear that content learning will be watered down if language learning takes some of the class time. Empirical results are conflicting on this issue. A review by Cañado (2018) found that CLIL did not water down content learning, and Surmont et al. (2016) even found gains in mathematics learning for CLIL vs. non-CLIL students. On the other hand, Fernández-Sanjurjo, et al. (2019) found CLIL students having a slightly weaker performance than non-CLIL students on subsequent content tests. A recent review by Cimermanova (2021) found no significant difference between CLIL and non-CLIL content learning outcomes, though there was a weak (but non-significant) advantage for non-CLIL.

Bruton (2013) criticized CLIL and its research, arguing that many studies have methodological weaknesses, such as selection bias (e.g., more ambitious students selected CLIL variants in the first place). Also, he considered the assumption of «two for the price of one» held by the most enthusiastic CLIL supporters to be unrealistic. Moreover, the learning of the second language will have a somewhat narrow focus towards discourse of the content domain, rather than more widely applicable mastery of the language.

Harrop (2012) makes an interesting analysis of the possibilities of CLIL, as well as its limitations. While the claim of increased language learning has been evidenced by many studies (though not all), she observes that a tension between content and language still exists, and for language learning, the lack of focus on form can lead to early fossilization of student errors. While CLIL may increase motivation for foreign language learning because there is an immediately added purpose (grasping the content of the course), this increased motivation does not seem to apply to all student groups. For some, CLIL increases the complexity. Students with low language proficiency may experience this as an extra hurdle towards learning the content. Another finding from some studies is that while middle and somewhat below middle students tend to benefit from CLIL, there are fewer students over-achieving with respect to the learning outcomes, indicating that over-achievement is likely capped by the extra complexity added by the foreign language.

COGNITIVE LOAD THEORY

Although PjBL, WIL, and CLIL have many differences, they have some clear similarities. All three posit that learning activities with a dual purpose (content and skills; theory and practice; content and language) can do better than the alternative of having two single purpose learning activities. To the extent that dual use of time implies trying to learn two things simultaneously, cognitive load theory might indicate that this is not always a good idea, as it would often recommend focusing at one thing to be learnt at a time (Paas et al., 2003). For instance, Edwards et al. (2020) found that learning syntax before problem-solving gave better results in CS1 (introductory programming) than a more integrated approach of learning syntax and problem-solving together. This would not make a PjBL approach to programming impossible, but at least indicate that some drill-oriented learning activities should precede the project, to ensure students have sufficient initial competence. Hence, such a course unit would have to be single purpose at least some of the time.

Leppink & Duvivier (2016) propose twelve tips for curriculum design from a cognitive load theory perspective, based on a three-dimensional taxonomy where student learning will gradually move from high support or scaffolding towards increased autonomy, from low to high task fidelity, and low to high complexity. While specifically targeting medical education, their general taxonomy of gradually increasing autonomy, fidelity and complexity could apply to most fields of education. Their tips are not in conflict with project-based or problem-based learning, and especially the latter has been used a lot in medicine. However, they do imply that early projects must in some cases be simpler, and less realistic, than an industry-style project. A case analyzed by (Peters, 2015) indicates how an open-ended, ill-formed project resulted in cognitive overload for first year students, concluding that they likely could have learnt more from a less complex project with a more scaffolded design.

There is limited literature in the intersection of cognitive load and WIL. However, on the duality of content and language, Roussel et al. (2017) claim that CLIL – with a dual purpose of teaching both content and language – is actually better than English Medium Instruction (e.g., teaching an engineering subject in English, although the students are not native English speakers). This because EMI will not take any measures to address the extra cognitive load resulting from the teaching of content in a non-native language, whereas CLIL – with its explicit purpose of teaching the language, can provide the measures for the students to overcome this load.

As cognitive load theory has mostly been researched in relation to the individual, there are few studies of cognitive load for students working in teams, as will typically happen in PjBL. However, Kirschner et al. (2018) discuss what they call collaborative cognitive load theory, which could apply to such situations. They find that collaboration can sometimes mitigate cognitive load, as the group develops a collective working memory which can contain more information than the working memory of any single individual, thus reducing the cognitive load on any single individual in the group. On the other hand, collaboration can in other cases aggravate cognitive load, specifically if there is cognitive load associated with conflicts and misunderstandings in the collaboration itself.

FRAMEWORKS FOR POSSIBILITIES AND PITFALLS

There are already some frameworks that can be used to understand possibilities for integrated learning, aiming for a dual purpose, rather than a singular content focus. One example is the

Taxonomy of Significant Learning proposed by Fink (2013). Unlike Bloom's taxonomy, which presents knowledge outcomes in a hierarchy of increasing levels of ambition, Fink's taxonomy identifies six kinds of learning: foundational knowledge, application, integration (seeing relationships between different parts of knowledge), human dimension (e.g., communication, collaboration, self-directedness), caring (having a genuine interest in the subject), and learning how to learn. Fink claims that these different kinds of learning are synergistic, thus a teacher does not have to give up on one kind of learning for the students to also achieve another. Hence, the "zero sum game assumption" often encountered in education redesign need not hold true. Dosmar & Nguyen (2021) describe experiences from designing a capstone project in biomedical engineering based on Fink's taxonomy, with strong learning outcomes and positive course evaluations from the students. Based on Fink's taxonomy, a dual (or even multiple) purpose for a course would be easier to achieve if combining different kinds of learning (e.g., foundational knowledge + application + caring), but harder if combining more of the same kind, say, foundational knowledge with some other foundational knowledge.

Cheng & So (2020) propose a typology and four models of ways for achieving integration in STEM learning. Three different types of integration are suggested: content integration, pedagogical integration and learner integration, and based on this they propose advice on how to achieve viable integrated courses. CLIL would likely be classified as content integration in their taxonomy (i.e., integrating two types of content, like an engineering subject and a foreign language), although from a CLIL researcher's point of view, the language would not be considered as content. WIL might to a larger extent be classified as pedagogical integration, of classroom pedagogy with learning through the work placement. PjBL might include several types of integration, e.g. integrating two subjects (say electrical engineering and mathematics) or a subject and an application domain (e.g., software engineering for a customer in finance). It could also imply pedagogical integration (various learning approaches used within the project, for instance as part of scaffolding for the content, or for effective collaboration) – and of course learner integration with students working in teams.

Our brief reviews of PjBL, WIL, and CLIL earlier in this paper indicate promising results for all of these – with many (though not all) empirical studies indicating that a dual-purpose course design need not reduce learning outcomes compared to having a singular purpose. On the other hand, some pitfalls have also been identified. Just like there may be a tension between content and language in CLIL, with teachers tending to identify as content experts, not language experts, so could there be a tension between content and skills in PjBL, teachers often experts in the engineering discipline, rarely experts in generic competencies like collaboration. Such tensions could have negative impact on the teaching and assessment of at least one of the outcomes. Finally, as indicated by cognitive load theory, a dual purpose need not cause cognitive overload for the students – a PjBL team project might sometimes instead reduce cognitive load due to establishment of a collective working memory. However, in other cases collaboration might increase cognitive load, and to avoid this, it is important that challenges related to collaboration are appropriately scaffolded relative to the level of the students and their prior experience with collaborative projects.

FINANCIAL SUPPORT ACKNOWLEDGEMENTS

This work was done in the context of the Excited Centre for Excellent IT Education, funded by HK-dir.

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