Can an intervention based on explicitly teaching problem-solving literacy affect problem-solving aptitude and engagement of students in humanities subjects?

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Abstract

The occupational demands placed on school leavers are rapidly evolving, with increased emphasis on problem-solving ability in the workplace. The significance of problem-solving has not gone unnoticed by the Organisation for Economic Co-operation and Development (OECD) who first integrated measurement of learners' problem-solving ability into Programme for International Student Assessment (PISA) 2003. This depth of investigation was expanded with PISA 2021 with the introduction of computer-based assessment (CBA) to track the process of problem-solving. This research explores how an understanding of problem-solving literacy can enable schools to develop learners' problem-solving ability. The literature review explores the need to develop a problem-solving literacy which can then be integrated into secondary schools. To investigate the effectiveness of introducing a problem-solving literacy, two groups comprising of Y12 and Y13 A-level Economics students were given the opportunity to participate in three problem-solving lessons. Participants were tested through CBAs delivered through the Vienna Test System (VTS) using the inventory for testing cognitive abilities (INT) test. Testing took place before and after problem-solving lessons had been delivered, with the aim of measuring the impact of the problem-solving lessons. In addition to the CBAs, participants were invited to complete a short online questionnaire to assess any changes in their views about problem-solving. Using statistical analysis, the results of the CBAs were analysed and there was found to be a positive correlation between the CBAs and attending problem-solving lessons. The sample size was too small to establish a causal relationship, but shows promise for the positive use of problem-solving lessons. Through examining participants' responses to the questionnaire, it was evident that participants had developed a positive rapport with the process. The study points towards the need for further research in the area, utilising a larger sample size in order gain a more comprehensive insight.

Keywords: problem-solving, computer-based assessment, CBA, Vienna Test System

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Table 1

Table of Abbreviations

Abbreviation	**Full term**
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
CBA	Computer-Based Assessment
VTS	Vienna Test System
INT	Inventory for testing cognitive abilities
KS	Key Stage
H_0	Null hypothesis
H_A	Alternative hypothesis
PR	Percentile ranking
n	Sample size
p	Probability
r	Correlation coefficient
z-score	Standard score
SE	Standard error
M	Mean
t	Hypothesis test statistic

Introduction

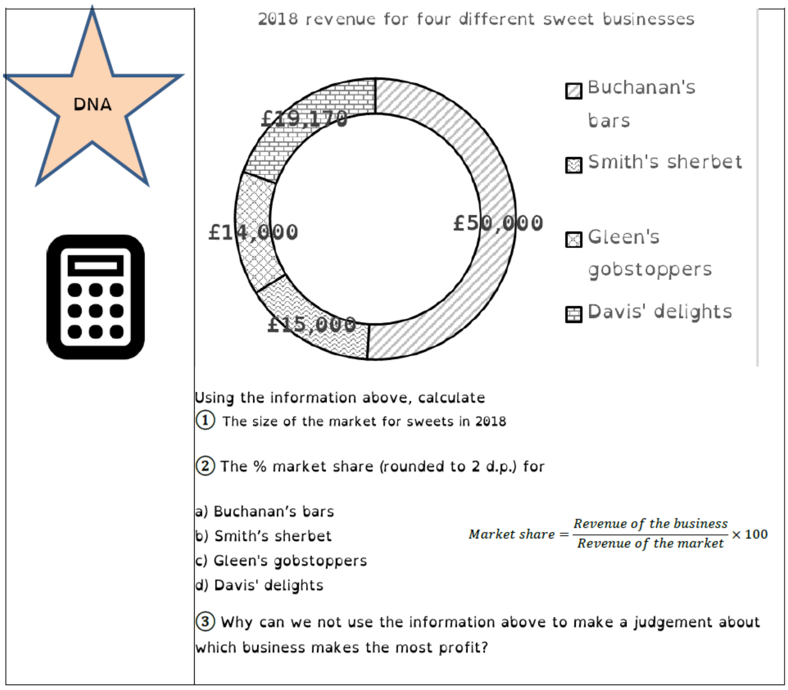
In my school I have taught across a range of subjects within the Maths and Humanities faculties, across a range of “key stages” (Education Reform Act, 1988). These subjects are Business (KS4, KS5), Economics (KS5), Geography (KS3), Religious Education (KS3), History (KS3) and Maths (KS3). In these subjects I have observed that learners are expected to exercise ‘problem-solving’. In this context, I am utilising Duncker’s (1945) definitions of problem and problem-solving

> A problem arises when a living creature has a goal but does not know how this goal is to be reached. Whenever one cannot go from the given situation to the desired situation simply by action, then there has to be recourse to thinking. Such thinking has the task of devising some action which may mediate between the existing and the desired situations. (p.1)

To elucidate the above definition, the Organisation for Economic Co-operation and Development (OECD) was referred to: “problem solving competency involves the ability to acquire and use new knowledge, or to use old knowledge in a new way, to solve novel problems (i.e. problems that are not routine)” (p. 13). To illustrate this definition within the context of my practice, an example of a problem that I have set students can be seen in the following handout (Fig. 1) that I created for use in lessons for both the subjects of Maths and Business.

Fig. 1

DNA: Calculating Market Share Handout



For clarity, Fig. 1 shows an example of a Do Now Activity (DNA). The activities are supposed to be 'self-contained' (require no input from the teacher to be completed or understood), and I have built the exercise accordingly. However, I have observed learners in the process of trying to complete the exercise and encountering a barrier. Although all the necessary resources to complete the exercise should be present and accessible to learners, some learners cannot navigate from the given state to the 'goal state' of completing the exercise. I have spoken to individual learners about their process of completing this exercise, and explained that all the information they could need is on their piece of paper. For part 2 of the exercise, I have pointed out that the formula that they need is present, and that I have observed them using formulas in their learning in the past. This falls within Csapó and Funke's (2017) description of problem-solving as a '21st century skill'

> Students will be expected to work in novel environments, face problems they have never seen and apply domain-general reasoning skills that are not tied to specific contents. (p. 19)

On the surface this problem appeared both 'well defined' and 'routine'. It appeared well defined because "the given state, goal state, allowable operators are clearly specified", and it appeared routine because I assumed "the problem solver already possesses a ready-made solution procedure" (Mayer and Wittrock, 2006, p. 288). In this example, being able to transfer the use of formulas constitutes the domain-general reasoning skill. 'Transfer' describes the use of prior learning in a new situation (Mayer and Wittrock, 1996). The learners who were not able to complete it had demonstrated failing in the transformation from a given state to a goal state, and therefore had not succeeded in problem-solving. Evidently for the learners who were not able to complete it, this problem-solving was not 'routine' either, as these learners did not know a method for solving this type of problem. Bassok and Novick (2012) help to articulate this phenomenon when they write "what constitutes a problem for one person may not be a problem for another person, or for that same person at another point in time (p. 413).

It is from this starting point that I first observed that the process of problem-solving within the classroom was worthy of examination.

Academics such as Lempert (2013) Sugrue (1995) have identified that problem-solving exists within other humanities subjects. Sugrue writes

> Some domains, such as … economics, and geography, lend themselves well to extraction of principles, rules, or laws. … An example of a principle in the domain of history might be that the underdevelopment of Third World countries is a function of colonization and specialization of production.
> (p. 32)

Building on this body of research, Author (2021) identified problem-solving taking place across the seven humanities subjects of "Geography, Business, History, Philosophy, Politics, Sociology, and RE [Religious Education]" (p. 25).

In the context of educational settings, problem-solving has developed a reputation for being an important transversal skill (Greiff et al. 2014), but also one which is not given sufficient attention as Mayer and Wittrock (2006) write "educators expect students to be able to solve problems using the material presented in the course but rarely provide problem-solving instruction" (p. 296).

The nature of occupational demands placed on workers are changing rapidly into the 21st century (see Autor & Dorn, 2009; OECD, 2010; Csapó & Funke, 2017; Funke, Fischer & Holt, 2018) with an increased in the emphasis placed on nonroutine skills (see Autor, Levy & Murnane, 2003). The importance of problem-solving within educational contexts is recognised by the Organisation for Economic Co-operation and Development (OECD) who have integrated measuring learners' problem-solving ability into their triennial Programme for International Student Assessment (PISA) study as of their 2003 and 2012 assessments (see OECD, 2014a; Csapó & Funke, 2017). The OECD (2019b) emphasise their intention to measure how well students are able to complete tasks in unfamiliar environments, writing "To do well in PISA, students have to be able to extrapolate from what they know, think across the boundaries of subject-matter disciplines, apply their knowledge creatively in novel situations" (p. 5).

The review of the literature provides significant insight into the current state of research about problem-solving, the need for the development of effective problem-solving literacy, and the importance of problem-solving for learners.

The line of enquiry under exploration is the possibility of learners becoming literate in the domain of problem-solving (the precise meaning of 'literate' in this context will be examined thoroughly further on). Through examining the literature on this subject area, and adjacent concepts, I then hope to put together an intervention for my learners. I will then attempt to measure the impact (if any) of this intervention.

Literature Review

Before addressing the teaching and assessment of problem-solving literacy I will first consult the relevant literature. First, I will consult the literature on the meaning of 'literacy' in an academic setting. Secondly, I will consult the literature on the meaning of 'problem-solving' in an academic context. Thirdly, it will then be necessary to give a brief overview of how 'problem-solving' currently fits within an educational context. Fourthly, I will narrow the focus and identify how 'problem-solving' fits within humanities subjects. Fifthly, I will examine what has been written about 'problem-solving literacy'.

What is 'Literacy'?

The word 'literacy' and 'literate' is (or was) used as a synonym for the ability to read and write (See Tyner, 1998; Gerber & Abrams, 2014). Gray (1956) wrote of literacy

> A person is literate when he [*sic*] has acquired the essential knowledge and skills which enable him to engage in all those activities in which literacy is required for effective functioning in his group and community, and whose attainments in reading, writing and arithmetic make is possible for him to continue to use these skills towards his own and the community's development. (p. 24)

This is not a neutral definition of literacy however, as it contained value judgements about what constitutes 'effective functioning' and 'community's development'. To attribute the quality of being 'functional' as a special classification of certain knowledge and skills reveals an implied importance to some knowledge and some skills over others. Stierer and Bloome (1994) succinctly describe this when they write [a]ttached to this hierarchy is an ascending scale of moral value and moral benefit" (p. 48). This is echoed by academics such as Papen (2005, p.7) who explains "these are not neutral definitions and 'literacy' is not simply a technical term, but that different concepts of reading and writing are grounded in specific discourses about literacy, about learning and about the learner".

This conception of literacy as a means to function effectively within a community has been reflected in government policy, with the DfEE (2001) setting out the rationale for their national strategy for improving adult literacy and numeracy skills as "to give all adults in England the opportunity to acquire the skills for active participation in twenty-first-century society" (p. 2).

The DfEE elaborate on this point, writing

> Employers, in particular, cannot compete in an increasingly global, knowledge-based economy without a workforce able to add real value at every level. One in five employers reports a significant gap in their workers' skills. And over a third of those companies with a literacy and numeracy skills gap say that they have lost business or orders to competitors because of it. Industry loses an estimated £4.8 billion a year because of poor literacy and numeracy skills. (p. 8)

It is evident that literacy is being conceived as a means to achieve economic outcomes. Academics such as Rassool (1999) have described the link between functional literacy as measured through quantifiable educational outcomes and 'economic needs'.

> On the one hand, we have literacy conceptualised as a set of technical skills, representing a quantifiable educational resource to be evaluated against economic outcomes criteria. Within this framework, jobs are matched with 'literacy skills', and skills with 'economic needs'. (p. 6)

Education transforming learners to meet the needs of a particular political order resonates with what Biesta (2010) described as the 'socialization function' of education "The socialization function has to do with the many ways in which through education, we become part of particular social, cultural and political "orders"." (p. 20).

More recently however, the term literacy has taken on extensive new meanings which go beyond skills gaps in the labour market. Bialostok (2002) illustrates this change in the way that literacy is conceived very clearly, writing

> The past two decades have been a watershed for researchers in the recognition of multiple literacies. Numerous scholars … have challenged the existence of a unitary or cognitively deterministic quality to literacy and have instead viewed literacy as a sociocultural and historical construct, the meanings and uses of which depend upon the social institutions and communities in which it is embedded. (p. 347)

Giroux (2005) reminds use that literacy is "both the mastery of specific skills and particular forms of knowledge" (p.1). Other academics, such as Papen (2005) have identified that different practices have their own distinct forms of literacy. Other academics explain that literacies are shaped by the distinct social activities and contexts to which they belong, that is to say that what is considered to be literacy will be different in different domains (see Barton and Hamilton, 2000). One example is offered by Lynch & Egede (2011) when describing the role medical literacy plays in optimising self-care of diabetes. They write "Health literacy, distinct from educational attainment, is conceptually defined as the ability to read and comprehend medical information" (p.953). This is a concept expanded on by the World Health Organisation (2015) when they write

> Health literacy refers to the personal characteristics and social resources needed for individuals and communities to access, understand, appraise and use information and services to make decisions about health. Health literacy includes the capacity to communicate, assert and enact these decisions. (p. 12)

Other examples include that ‘political literacy’ described by Young (2000, p.20) as “understood as the knowledge and skills needed for citizenship”, and that of ‘computer literate’ and ‘technology’ literate (see Gurak, 2001). For the purposes of the PISA the OECD relies on numerous other forms of literacy, each shaped by the context in which they belong. These are scientific literacy, reading literacy, mathematical literacy, and financial literacy. In their assessment framework the OECD (2017) defines financial literacy as

> … knowledge and understanding of financial concepts and risks, and the skills, motivation and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life. (p. 87)

The Department for Digital, Culture, Media & Sport (DCMS) Online Media Literacy Strategy sets out a working definition of ‘media literacy’ (p. 13). It is evident from the above literature that the meaning of ‘literacy’ extends far beyond the ability to read and write. Auerbach et al. (1997) contribute to the discourse when they write “What counts as literacy changes depending on the historical time, the place, the purpose and the people” (p. 6). Gray (1956, p. 7) elucidates this concept thus “different concepts of reading and writing are grounded in specific discourses about literacy, about learning and about the learner”

What is ‘Problem-Solving’?

As referenced earlier, Duncker’s (1945) definition of problems and problem-solving provides a definition broad enough to accommodate the range of academic problem-solving tasks that require creative solutions. There are important clarifications that emerge from the academic literature.

First of all, it worth identifying the distinction academics make between ‘routine problem-solving’ and ‘creative problem-solving’. Mayer (1997) provides us with the succinct definition of ‘routine problem-solving’ when he describes it as “routine problem solving occurs when a problem solver already knows a method for solving a given problem” (p. 476). Mayer gives the example of solving a long division problem. Once the method to solving long division is learnt, this becomes ‘routine’. In contrast, ‘creative problem-solving’ is described as “when a person has a goal but does not know how to accomplish it” (p. 476). Comparing these two different kinds of problem-solving to Duncker’s definition of problem-solving (1945) it becomes apparent that, of these two, Duncker is referring to ‘creative problem-solving’. From this point onwards, the term ‘problem-solving’ will be used to convey the meaning of ‘creative problem-solving’.

Secondly, it is worth examining another similar definition of problem-solving, this time from Mayer and Wittrock (2006)

> When you are faced with a problem and you are not aware of any obvious solution method, you must engage in a form of cognitive processing called *problem solving.* (p. 287, italics in original)

Mayer and Wittrock’s conception of problem solving is that it refers to a kind of ‘cognitive processing’. From this point onwards, the term ‘problem-solving’ will be used to convey the meaning of ‘problem-solving’, ‘thinking’ and ‘cognition’ interchangeably based on the general definition which can apply to all of them. This follows the legacy of Mayer (1983) who also found it convenient to do as much.

Thirdly, problem-solving can be analysed as a number of subprocesses. These can include ‘general orientation’, ‘problem definition and formulation’, ‘generation of alternatives’, ‘decision making’, ‘verification’, (see D’Zurilla & Goldfried, 1971) ‘representation’, ‘planning’, ‘executing’, and ‘self-regulating’ (see Mayer and Wittrock, 1996; Mayer and Wittrock, 2006). Some of these subprocesses will be explored in more detail. However useful these classifications may be, Bloom & Broder’s (1950) prudent observation that “any such system of categorization must results in a loss of much of the essence of the particular process.” (p. 90) should not be overlooked. From this point onwards, the term 'problem-solving' will be used to convey any combination of its component subprocesses unless otherwise specified.

Fourthly, a number of academics have found it necessary to make the distinction between 'problem-solving' and 'complex problem-solving' (CPS). In their review of 20 years of CPS research, Frensch and Funke (1995) integrated a number of different interpretations into the following definition:

> … the given state, goal state, and barriers between given state and goal state are complex, change dynamically during problem solving, and are intransparent. The exact properties of the given state, goal state, and barriers are unknown to the solver at the outset. (p. 18)

However, other academics have identified that, for the purposes of practical assessment of school students, there is no formal basis by which to make the distinction between complex and non-complex problem-solving (see Osman, 2017, p. 48). From this point onwards, the term 'problem-solving' and 'complex problem-solving' will be used as interchangeable synonyms.

Contextualising Problem-Solving in Education

As referred to above, the OECD most recently integrated measuring learners' problem-solving ability into PISA 2012. As all the students who participated in the PISA 2012 problem-solving study also had mathematics, reading, and science scale scores, it was possible to calculate latent correlations in three core domains and problem solving (see Dossey & Funke, 2016). The OECD's (2014a) analysis of the PISA 2012 indicated that, on average, 68% of the variance in problem-solving ability score was explainable by the variance in the other three assessment domains. The remaining 32% of the variation is therefore explained by problem-solving ability captured by the assessment of problem-solving. Using this analysis, Csapó & Funke (2017) suggest

> … improving problem solving requires something other than teaching the main domains well. … Although the reasons for these differences cannot be precisely identified based on the available data from this assessment, it is clear that the teaching and learning methods used in some countries are more effective at developing problem solving than

others. (p. 22)

These results suggest there is opportunity for additional research on improving problem-solving within an educational context. For more than 40 years academics have explored the problem of the deficit of problem-solving being taught in schools. Norman (1980) insightfully contributes

> We expect students to solve problems yet seldom teach them about problem solving. … We need to develop the general principles of how to learn, how to remember, how to solve problems, and then to develop applied courses, and then to establish the place of these methods in an academic curriculum. (p. 97)

This sentiment is shared by Simon (1980) who argues that are general problem-solving skills which would be invaluable across a range of different disciplines, which are not currently being taught. This is echoed by academics such as Mayer (1997), who writes

> As educators, we expect secondary school students to be able to solve problems. … Yet, in spite of our expectations about students' problem solving, we sometimes fail to provide adequate opportunities for students to become problem solvers. All too often, problem solving becomes part of the hidden curriculum in high school and junior high school--a topic that we expect students to learn but often fail to teach. (p. 473)

Here Mayer refers to ‘the hidden curriculum’. Martin (1976) elucidates the meaning, writing “The contrast is between what it is openly intended that students learn and what, although not openly intended, they do, in fact, learn.” (p. 136). The way that Mayer used the term ‘hidden curriculum’ in this context appears to be dissimilar to how Jackson (1968) who first coined ‘hidden curriculum’ uses term. Jackson was describing the social interaction, rule following, and relationship-building demands that are made of students in school. He describes these social aspects as follows

> … the crowds, the praise, and the power that combine to give a distinctive flavor to classroom life collectively form a hidden curriculum which each student (and teacher) must master if he is to make his way satisfactorily through the school. The demands created by these features of classroom life may be contrasted with the academic demands — the "official" curriculum, so to speak — to which educators traditionally have paid the most attention. (pp. 33-34)

From this point onwards, any reference made to a 'hidden curriculum' is meant to convey the meaning as Mayer intended.

Assessing the place of problem-solving within education has been a feature of the literature for more than 70 years. Bloom & Broder (1950) commented on the fact that, in classroom discussions, more emphasis is placed on the accuracy of responses rather than the methods by which they are arrived at. Good mental processes (such as that of problem-solving) are thought of as the important outcome of education, with particular solutions to classroom problems serving only to indicate the quality of students' thinking (p. 3).

Other academics have noted the change in attitude towards schools providing problem-solving instruction. Ruscio and Amabile (1999) write

> The development of problem-solving ability has often been regarded as a primary goal of the education process. Although school administrators have traditionally advocated for the instruction of such basic skills as reading, writing, and mathematics … there has been an increasing emphasis in more recent years on the importance of promoting general thinking and reasoning skills that enhance student's ability to solve novel and unusual problems. (p. 251)

Moula (2017) makes an argument to 'develop a program for social problem-solving literacy', which is he goes on to the justify this argument writing

> … as we see, learning "general problem-solving" is recognized as an important issue, however, there is no particular subject devoted to this task. General problem solving means problems that are not directly connected to any specific subject, for example, problems in mathematics or physics. (p. 7)

Reading these descriptions, it becomes evident that the absence of a problem-solving literacy has been felt keenly by educators for decades.

The particular demands that will be placed on modern school leavers has been explored by academics such as He et al. (2017), Kiili, Mäkinen & Coiro (2013), Weinstein & Mayer (1986), and D'Zurilla and Goldfried (1971) who particularly stress the importance of problem-solving ability in the face of a modern, and therefore dynamic, society. Fuson (1992) describes how the characteristics of modern society (particularly powerful computers) has reconfigured the way that students relate to problem-solving, writing that "children now need to be problem solvers and problem posers, not just calculators" (p. 55).

Recognising the necessity to assimilate problem-solving into the curriculum, Anderson et al. (2001) created a revised version of Bloom's taxonomy of educational objectives, which broadened to incorporate educational objectives to aimed at promoting transfer (p. 63). The revised taxonomy was expanded to include two dimensions, the knowledge dimension and the cognitive process dimension (p. 5). The cognitive process dimension contains six categories of cognitive process, these being (from simple to complex) 'remember', 'understand', 'apply', 'analyse', 'evaluate', and 'create'. Of these, 'remember' is closely related to retention, while the other five increasingly relate to transfer. The knowledge dimension includes 'metacognitive knowledge' which includes "… knowledge of the general strategies for learning, thinking, and problem solving" (p. 56), and "Knowledge that general problem-solving heuristics may be most useful when the individual lacks relevant subject – or task – specific knowledge" (p. 59).

Bloom & Broder (1950) identified that variations in students' problem-solving could be used to better design school curriculums. They argue that the measurement of the products of problem-solving are crude, and that the measurement of problem-solving would provide a more meaningful insight into how education had changed leaners.

Contextualising Problem-Solving Within Humanities Subjects

I will now turn my attention to academic literature which can provide an insight into the nature of problem-solving situated within humanities subjects.

The exact classification of which subjects fall under the umbrella of 'humanities' is subject to ongoing debate among academic (Clarke & Wrigley, 1988). Following their example, I will be defining 'humanities subjects' as those which are taught in the humanities faculty. From this point onwards, the term 'humanities subjects' will be used (unless otherwise specified) to convey any combination of the subjects Business, Economics, Geography, History, Philosophy, Politics, Psychology, Religious Education (RE), and Sociology.

Author (2021) identified classroom problem-solving in a range of humanities subject areas. Some examples identified are “How can Meontown be spared from coastal erosion?” (Geography), “asking students to identify, or identify uses for, artefacts” (History), and “Deciding which theory would be best to explain/analyse a given phenomena” (Sociology) (pp. 41-57). Other academics have researched children’s conception of economics including their conception of examples of problem-solving within the subject, an example being “To solve the problem of poverty” (Berti, Bombi & Duveen, 1988, p. 13).

Having examined the literature relevant to problem-solving within humanities subjects, it is apparent that many of the examples of problems identified either an initial (or given) state, a goal state, allowable operators, and/or constraints not clearly specified at the outset. These problems are therefore “ill-defined” (Mayer & Whittrock, 2006).

Problem-Solving Literacy

Thus far, having established that ‘literacy’ is broad term that encompasses different skills depending on the context in which is it is situated, and having established that problem-solving is something that educational practitioners should be concerned with, I will now turn to the area of ‘problem-solving literacy’. Within the PISA framework, the OECD (2019a) lays out their conception of “literacy” as one being specifically tied to students’ problem-solving ability:

> PISA’s unique features include its: … **innovative concept of “literacy”**, which refers to students’ capacity to apply knowledge and skills, and to analyse, reason and communicate effectively as they identify, interpret and solve problems in a variety of situations. (p. 13, bold in original)

Barton and Hamilton remind us that “we can say that domains present ‘particular configurations of literacy practices” (2000, p. 44). It is to literacy with the domain of problem-solving that I now turn my attention.

With respect to the significance of equipping learners with particular literacies (in this case, problem-solving literacy), Papen (2005) writes

> … literacy practices are linked to institutional contexts and power structures in society … Individuals and groups who possess these literacies are likely to have an advantage over those who don't (pp.48-49)

The task of identifying the elements that make up a problem-solving literacy has been examined by academics Youssef-Shalala et al. (2014) who express this endeavour as

> The search for general problem-solving strategies that transcend specific domains has been a goal of researchers in the field of cognitive processes and instructional design for many decades (p. 215)

They go on to illustrate the difference between 'general strategy' and 'domain-specific strategy' with the following example.

> … learners faced with a problem such as, (a + b)/c = d, solve for a, need to learn that the appropriate initial move for some categories of algebra problems is to multiply out the denominator on both sides of the equation. This problem-solving strategy is highly effective in solving some categories of algebra problems but useless in unrelated areas and so is domain specific rather than general. (pp. 215-216)

On envisioning what problem-solving literacy to inform a general strategy could look like, Mayer and Whittrock (2006) offer seven approaches. They refer to these as means to 'Promote Problem-solving transfer'. Youssef-Shalala et al. (2014) usefully offer this insight to explain the significance of promoting transfer this in context when they write "By its very nature, an effective general problem-solving strategy will be usable in different domains, and hence promote transfer" (p. 215). These seven approaches have explicitly been conceived using Katona's 'Meaningful methods' of instruction, as opposed to 'Mindless methods' of instruction. Katona helpfully illustrates his concept of 'meaningful method' when he writes "Teaching should if possible ensure the right or intended kind of understanding in the greatest possible number of subjects" (1940, p. 730). That is to say, the method is meaningful when it helps the learner in to address unfamiliar and novel problems. This resonates with Youssef-Shalala et al.'s notion of problem-solving literacy being usable to address novel problems across numerous domains.

Gestalt psychologist Wertheimer (1945) illustrates the concept of teaching 'Meaningful methods' over 'Mindless methods' through his accounts of teaching mathematics. In his description of teaching how to find the area of a parallelogram, he contrasts the 'rote' method of finding the area of a parallelogram "the area of a parallelogram is equal to the product of the base by the altitude, establishing the equality of certain lines and angles and the congruence of the pair of triangles" (p. 15).

Although the students were able to use this method to calculate the area of parallelograms with lengths of different sizes, there existed a serious lack of skill with respect to problem-solving transfer. He identified that the students were unable to use this method to determine the area of the parallelograms which were the same as the original figure given by the teacher when they were simply rotated. The students were only able to apply the method in routine cases. He characterises the method as being "blind to the issue of *how the area is built up* structurally" (p. 34), and so ends up providing no insight into the problem. He goes on to conclude that such a method is not conducive to being transferable to the general problem of area-determination (p. 77). This distinction between learning something and being able to use it in a routine context and learning something and being able to use it in a new, unfamiliar domains was later classified by Salomon and Perkins (1989) who drew a distinction between 'transfer' and 'mere learning' (p. 115). They illustrate this difference using the example of a student learning historical dates to reproduce them in a written test as an example of 'mere learning' rather than of 'transfer'. Mayer (1997) would explain this pattern as reflecting 'rote learning' (p. 475). The problem of establishing if a context is sufficiently different to count as 'transfer' is not straightforward, Salomon and Perkin (1989) go on to write "when do we call two behaviors or contexts "the same"? Evidently, there is no hard criterion. We draw such lines according to our intuitions, which differ somewhat from person to person" (p. 115). Anderson et al. (2001) illustrate the distinction when they write that retention focuses on the past; transfer focuses on the future. They give the example of students reading a textbook on Ohm's law. A retention test, they suggest, could ask students to write the formula for Ohm's law. This contrasts with what might be found in a transfer test, which could ask students to "rearrange an electrical circuit to maximise the rate of electron flow" (p. 63) or "use Ohm's law to explain a complex electric circuit" (p. 63).

As well as not adding anything positive to problem-solving when encountering novel problems, prior experience of mindless methods can cause hinderances for problem-solvers (see Mayer, 1986). This can be partly explained by what Duncker (1945) refers to as "functional fixedness", which he defined as "fixedness as the result of a function dissimilar to that demanded" (p. 85). Duncker demonstrated this phenomenon with a series of five experiments. One such experiment he referred to as the "box problem". The goal was to a mount three candles vertically, side by side, on the door at eye height. Half of the participants were given three small boxes one containing several candles, another containing tacks, and the third containing matches. The other half of the participants were given the same materials, but with the candles, tacks, and matches not contained in the boxes. Duncker was contrasting when he called the 'usual function' of objects against a 'new, unusual function'. He explains the solution as "with a tack apiece, the three boxes are fastened to the door, each to serve as platform for a candle" (p. 86).

In this example 'usual function' of the boxes is given as 'container', while the 'new, unusual function' is given as 'platform'. Controlling for special prominence of any of the objects, Duncker observed that when the subjects encountered the boxes as performing their 'usual function' of containers, it was harder to discover a new function. He concludes "therefore we can say: *Under our experimental conditions, the object which is not fixed is almost twice as easily found as the object which is fixed*" (p. 87, italics in original).

This finding suggested to Duncker that past experiences of encountering boxes as containers limited the ability of the participants to consider other functions. For this example, transfer had taken place as the subjects' prior experience impacted their ability to solve novel problems in the future. What this example illustrates is 'negative transfer', which Mayer and Whittrock (1996) described as "when previous problem-solving experience (or learning) hinders performance on solving new problems (or new learning)" (p. 48).

Mayer and Whittrock (2006) make a distinction between methods of teaching which allow the domain-specific skills learnt to be transferred into new domains, and addressing problem-solving transfer through directly teaching problem-solving skills. They propose seven meaningful methods which promote teaching problem-solving transfer:

Table 2

Seven Ways to Promote Problem-Solving Transfer

Instructional method	Example
Load-reducing methods	Automaticity, constraint removal
Structure-based methods	Concrete manipulatives
Schema-based methods	Advance organizers, pre-training, cueing
Generative methods	Elaboration, note-taking, self-explanation, questioning
Guided discovery methods	Guided discovery
Modelling methods	Worked examples, apprenticeships
Teaching thinking skills	General courses, specific strategies

(Mayer and Whittrock, 2006, p. 290)

Methods 1-6 are “based on teaching content in ways that would facilitate its usability in subsequent problem solving” (p. 296). What they mean by this, is teaching domains-specific skills which can then be utilised for problem-solving in unfamiliar areas. Referring back to the example of the problem in the introduction, if using formulas had been taught using a method with more effective problem-solving transfer this has the potential to alleviate the barrier to preventing the transition from the ‘initial state’ to the ‘goal state’ of completing the exercise.

I am more concerned with the seventh method however, which is the approach of teaching problem-solving. Mayer and Whittrock refer to as ‘teaching thinking skills’. A number of courses have been created to teach problem-solving skills. Mayer (1997) proposed four recommendations concerning what, how, where, and when to teach. These were based on a review of the research on teaching problem-solving skills. A summary of his recommendations follows (see Mayer, 1997, pp. 488-489).

1. What to teach? Mayer argues that a problem-solving curriculum should avoid trying to improve general intelligence. Instead he recommends focusing on component skills. He gives examples of summarising passages, using diagrams to represent story

problems, essay planning, writing test hypotheses in mystery scenarios, and how to coordinate these component skills when engaging in academic tasks.

2. How to each? Mayer argues that a problem-solving curriculum would prioritise methods used for the process of problem-solving (so this could include, for example, ‘thinking’ and ‘cognition’) over getting the correct final answer (which he calls the product of problem-solving). He illustrates this distinction he recommends that students should engage in discussions about how to problem-solve realistic academic problems instead of “drill and practice on contrived and isolated parts of an academic task” (p. 488).

3. Where to teach? Mayer argues that a problem-solving curriculum should not exist as a stand-alone course, but instead should be integrated into the different subject areas. He argues that problem-solving skills are better learnt when they within the context of the kinds of problems that learners will have to solve. This is because “techniques for representing problems or planning solutions are different in each domain” (p. 488), so that it follows that the problem-solving skills should be learnt within the relevant domain.

4. When to teach?

While Mayer acknowledges that problem-solving necessitates not allowing working memory to be dominated by thinking about basic component skills, Mayer argues against designing a problem-solving curriculum around ‘prior automatization’, which Mayer (1987) described as” a student should be able to perform basic component skills effortlessly before learning to solve complex problems that require those skills” (p. 55).Such an approach would condemn a learner to having to memorise a range of low-level skills before having the opportunity to engage in problem-solving. Mayer instead suggests that a problem-solving curriculum should utilise ‘cognitive apprenticeship’. This is where learners engage in problem-solving while utilising assistance from others to remove the constraint of requiring significant mental effort of thinking about component skills. Mayer draws upon Tharp and Gallimore’s (1988) concept of ‘assisted performance’ (p. 30). The difference between the problem-solving a learner can achieve assisted in contrast to unassisted resonates with Vygotsky’s (1978) ‘zone of proximal development’ (ZPD), which he described as follows “*it is* *the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers.*" (p. 86, italics in original). Through these recommendations, Mayer provides a guidance as to what would constitute an effective problem-solving curriculum. Mayer and Wittrock (2006) went on to apply these recommendations to evaluate Bloom & Broder's (1950) example of teaching thinking skills within the humanities subject of economics. In their assessment they praised the program for its focus on component skills, the emphasis on the process of problem-solving over the product of problem-solving, and being taught within the context of the subject domain. They also recognised that the learners in question were already equipped with the knowledge of the fundamentals of economics, and so the basic skills were already developed. They judged the program to be consistent with first second, and third criteria, but not consistent with the fourth criterion.

Moula, who also explored the meaning of problem-solving literacy, explains the priorities in his vision when he writes

> … the most important difference between this and other types of working is that here the focus is on thinking and problem solving. We did not push pupils to memorize facts. The pupils have definitely developed their capacity to think systematically. (p. 55)

What is apparent across the literature is that the recognition on the part of academics of the potential of using research to help equip learners for problem-solving.

According to Bassock and Novick (2012) researchers have identified regularities in the ways that problem-solvers (a) represent, or understand, the problem they are trying to solve, and (b) search for the solution to their problem (p. 414). These constitute two subprocesses of problem-solving.

Problem Representation: The Gestalt Legacy

With respect to (a) problem representation, Gestalt psychologists extend the organisational principles of visual perception to the problem-solving domain (see

Wagemans et al., 2012). They demonstrated how principles present in visual perception directly correspond with how problem-solvers relate to problems with a visual element. Bassock and Novick (2012) explain this very plainly when they write

> The principles of visual perception (e.g., proximity, closure, grouping, good continuation) are directly relevant to problem solving when the physical layout of the problem, or a diagram that accompanies the problem description, elicits inferences that solvers include in their problem representations. (p. 416)

Given than visual aspects of a problem affect the perception of the problem, and thus how the problem is 'represented' to the problem-solver, by extension they affect the ability to problem-solve). An example of where a principle of visual perception feeds into the process of problem-solving can be found when attempting to solve the "nine-dot problem" (see Maier, 1930). The nine-dot problem, and one possible solution are reproduced below.

Fig. 2
The Nine-Dot Problem and Solution

The figure originally presented here cannot be made freely available via ORA because of copyright. The figure was sourced at van Steenburgh, J. J., Fleck, J. I., Beeman, M., and Kounious J. (2012) 'Insight', in Holyoak, K. J. and Morrison, R. G. (Eds.) The Oxford Handbook of Thinking and Reasoning. Oxford: Oxford University Press. doi:10.1093/oxfordhb/9780199734689.013.0021 .

van Streenburgh et al. (2012) succinctly explain the nine-dot problem thus "the nine-dot problem. (Left) Subjects' task is to draw four straight lines that go through all nine dots without backtracking or lifting the pencil from the paper. (Right) One solution to the problem" (p. 7).

This problem specifically is affected by the Gestalten law of Prägnanz, which Wagemans et al. (2012a) succinctly describe as "in its most general sense, that the perceptual field and objects within it will take on the simplest and most encompassing (ausgezeichnet) structure permitted by the given conditions" (p. 1177).

Problem-solvers finds it difficult to discover an answer which would involve them working outside of the square boundary implied by the nine-dot array (see Chronicle, Ormerod & MacGregor, 2001). As Öllinger et al. (2013) explain

> One source of difficulty in the nine-dot problem is that problem solvers initially only consider moves that remain within the 3 × 3 grid (due to a perceptually driven *boundary constraint* that keeps lines within the perceived 3 × 3 square). (p.268, italics in original)

If problem-solvers were to be aware of some the principles present in visual perception, and recognise when these were hindering problem-solving, I postulate that they may be able to override the constraints imposed by this principle through conscious control. An understanding of the Gestalt legacy and its impact on problem-representation could therefore form part of problem-solving literacy. I will return to the Gestalt legacy below, when describing barriers when engaging in problem-solving.

Searching for Solutions: The Legacy of Newell and Simon

With respect to (b) generating the solutions in problem-solving, Newell and Simon conceptualised problem-solving as a process of navigation through a 'problem space'. Simon (1978) described this 'problem space' of consisting of the following elements

1. Knowledge states, ranging from the initial state, the desired end state and all states in between. These represent the 'nodes' in the problem space

2. Operators, which are used to move from one knowledge state to another

3. Constraints, such as what operators legal and what the defines the goal knowledge state

4. Information about how to navigate the path from the current state to the next one, which includes some memory of the previous position

Newell and Simon observed that people's search used heuristics, which are likely to help solve the problem without an extensive amount of search to (see Bassock and Novick, 2012). One such heuristic is the "means-ends analysis" (Newell and Simon, 1972, p.416). Bassock and Novick (2012) succinctly describe this heuristic as follows:

> … it consists of the following steps: (*1*) Identify a difference between the current state and the goal (or *subgoal*) state; (*2*) Find an operator that will remove (or reduce) the difference; *(3a)* If the operator can be directly applied, do so, or *(3b)* If the operator cannot be directly applied, set a subgoal to remove the obstacle that is preventing execution of the desired operator; (*4*) Repeat steps 1–3 until the problem is solved. (p. 419)

If problem-solvers were to recognise when they were navigating through a 'problem space', and were conscience of heuristics, I postulate that it is possible to reduce the amount of search time required. An understanding of the Newell and Simon legacy could therefore form part of problem-solving literacy.

Barriers When Engaging in Problem-Solving: External Representation, and Problem Orientation

I will now turn my attention to the literature which describes barriers problem-solvers encounter. I will first examine external representations, which refers to the Gestalt legacy and principles of visual perception. Second, I will steer towards the interference on problem-solving as caused by students' attitude and worry.

Academics have examined the role of external representations (ERs), such as diagrams, in the problem-solving process (see Greene, 1989; Barwise & Etchemendy, 1996). ERs are an effective aid to reasoning due to their cognitive effects (Cox & Brna, 1995). Novick & Catley (2007) built upon this body of work, examining the consequences on problem-solving of various graphic design decisions. In their experiment, subjects were asked to translate information between different diagram formats which are 'informationally equivalent'. What they determined was that, although the diagrams were 'informationally equivalent', they were not 'computationally equivalent'. Novick & Catley are drawing on Larkin & Simon's (1987) definitions. Groups of diagrams are 'informationally equivalent' when "all of the information in the one is also inferable from the other, and vice versa" (p. 67), and 'computationally equivalent' when

> … they are informationally equivalent and, in addition, any inference that can be drawn easily and quickly from the information given explicitly in the one can also be drawn easily and quickly from the information given explicitly in the other, and vice versa. (p. 67)

Larkin & Simon add the important caveat that ‘quickly’ and ‘easily’ are not precise terms. Novick & Catley’s (2007) research data supported their hypothesis that “the Gestalt principle of good continuation interferes with participants’ ability to extract the critical structural information regarding hierarchical levels from a ladder and to create ladders that appropriately depict a given hierarchical structure” (p. 206).

Wertheimer (2012) defines this principle as “the tendency that parts that create coherent continuity are grouped together” (p. 185). If problem-solvers were to recognise when their visual perception may be shaped by the principle of good continuation, I postulate that that they may be able to override the constraints imposed by this principle through conscious control. An understanding of the principle of good continuation and its impact on problem-representation could therefore form part of problem-solving literacy. When considering what a problem-solving literacy should contain, it would be unsatisfactory not lend some consideration to towards students’ attitude towards problem-solving. Bloom & Broder (1950) define ‘attitude’ as “emotions, values, and prejudices of the student as they are involved in the attack on problems” (p. 30). In their research they identified three distinct kinds of attitudes which impacted the problem-solving ability of students (p. 31).

1. Attitude towards reasoning. This attitude hindered problem-solving when students believed that reasoning was not important in the process, instead one either knows the answer to the problem or not.

2. Confidence in their ability to solve the problems. This attitude hindered problem-solving when students became discouraged from engaging with the mental process. This would result in students not trying, making a superficial attempt to reason, or attempting to solve the problem trough guessing.

3. Introducing personal considerations into their problem-solving. This attitude hindered problem-solving students in two ways (a) not divorcing their personal convictions from the problem. This was salient when faced with an element such as ‘assume the

following statements are true'. (b) choosing answers which better fitted their values over the correct answer which they had used reason to arrive at. This continues to be identified in the classroom, as demonstrated in by Author (2021) who writes "some students have will take answering RE or Philosophy papers as a matter of personal dignity. They will answer as though preaching from a soap box, ignoring all learning and advice." (p. 46).

Dugas et al.'s (1998) cognitive-behavioural model describes of four elements which interfere with problem-solving (pp.216-217):

1. Intolerance of uncertainty. Furnham (1994) defines this as "the way an individual (or group) perceives and processes information about ambiguous situations when they are confronted by an array of unfamiliar, complex or incongruent cues." (p. 403).

Where problem-solvers are not tolerant of uncertainty (which novel problems are by their nature) this interferes with problem-solving.

2. Beliefs about worry. Dugas et al. (1998) offer the examples of "worrying helps avoid disappointment" and "worrying helps find a better way of doing things" (p. 216).

3. Poor problem orientation. This refers to an individual's awareness and appraisals of problems, and of their problem-solving (Maydeu-Olivares & D'Zurilla, 1995). When problem orientation is improved, this enables better problem-solving ability (see Dugas et al., 1998, p. 224).

4. Cognitive avoidance. This refers to the process avoiding threatening mental images. This negatively impacts problem-solving as Kim and Grunig (2021) remind us "novel problems can be very threatening" (p. 215).

If problem-solvers were to identify when they demonstrating one or more of the attitudes laid out by Bloom & Broder, I postulate that it may be possible to adapt this attitude thus reducing the interference of problem-solving. If problem-solvers were to recognise when they were experiencing worry that was hindering the process of their problem-solving, I postulate that it is possible to reduce the amount of search time required. An understanding of how attitude and worry interferes with problem solving could therefore form part of problem-solving literacy.

Method

Research Questions Arising From the Literature Review

The review of the literature led me to develop the following research questions which would define the parameters of my research. Here I am drawing upon Lewis and Munn's description (1987, p. 5) "research questions are the vital first steps in any research. They guide you towards the kinds of information you need and the ways you should collect that information."

Main Research Question

Can an intervention based on explicitly teaching problem-solving literacy improve problem-solving aptitude and attitude of students in humanities subjects?

Research Sub-Questions

• (**RQ1**) The first sub-question is framed as a hypothesis.

H_0: Teaching problem-solving literacy to learners does not result in statistically significant better problem-solving aptitude as measured through computer-based assessments.

H_A: Teaching problem-solving literacy to learners results in statistically significant better problem-solving aptitude as measured through computer-based assessments.

This research question emphasises that any improvement in problem-solving ability should be correlated with being taught problem-solving literacy, rather than being the result of other variables.

• (**RQ2**) Does gender, year group, or membership of a specific comparison group significantly impact changes in problem-solving ability?

This research question is designed to examine if variation in changes to problem-solving ability are the result of variables beyond the control of the researcher. Additionally, it can lend some insight to methodological weaknesses. If the results reveal that improvement in problem-solving ability is closely tied to gender, this may reveal the existence of a sexist bias in the way that the project was delivered. Similarly, it is an intended outcome of the intervention that all participants receive the potential benefit of the intervention. If the results reveal that improvement in problem-solving ability is closely tied to comparison group, this may reveal the existence of a bias in the way that the project was delivered.

• (**RQ3**) How does the teaching of problem-solving affect students' attitude towards problem-solving?

This research question is designed to examine if the intervention can meaningfully affect participants' attitudes towards problem-solving, with attitude being identified as a barrier to problem-solving. The meaning of 'attitude' being used in as defined by Bloom & Broder (1950).

Participants

Participants in the research were 29 mixed gender A-level Economics students studying at the sixth form of a secondary comprehensive school. Students were recruited via an Economics lesson taught by myself. A short amount of time was taken out of the lesson to explain to the students about the nature and purpose of the research project, what would be required from participants, and the meaning of problem-solving for the purposes of the research. All students were explicitly made aware that their participation was voluntary, that they could withdraw at any time for any reason, and that this research would not impeded their A-level Economics lessons. They received biscuits in exchange for their participation.

Summary of Intervention

Participants were asked to complete a CBA to measure their problem-solving aptitude using the Inventory for testing cognitive capabilities (INT) software. Participants were then randomly split into two comparison groups, referred to as 'Group A' and Group B'. Participants followed an intervention schedule summarised in the table below.

Table 3

Schedule of Interventions

Group A	Group B
Initial CBA	Initial CBA
Problem-solving lesson 1: The Gestalt legacy Problem-solving lesson 2: Newell and Simon legacy Problem-solving lesson 3: Problems encountered when engaging with problem-solving	
Second CBA	Second CBA
	Problem-solving lesson 1: The Gestalt legacy Problem-solving lesson 2: Newell and Simon legacy Problem-solving lesson 3: Problems encountered when engaging with problem-solving
Final CBA	Final CBA
Questionnaire	Questionnaire

When designing the research an important decision was made between having one group follow the intervention, leaving the other group as a control group, or having both groups follow the same intervention, thus creating comparison groups. It was decided that both groups should follow the intervention. The rationale for splitting participants into two comparison groups was twofold:

1) This allowed all students to get the potential benefit of the intervention
2) This created two different data sets, which could then be compared

Each problem-solving lesson took place during the morning breaktime of a school day. For a given group, the lessons took place on a Tuesday, Wednesday and Thursday of the same calendar week. The format of each of the problem-solving lessons is consistent, with the desired learning outcomes being made clear at the start of each session. This is line with the with the work of academics such as Laurel (2008) who stress the importance of learning objectives (referred to as ‘learning questions’) being known to learners for effective learning. For each lesson participants were also given a printed handout which contained the key terms and definitions for relevant concepts that they would encounter during the session.

I will now outline the content three problem-solving lessons which form the basis for the intervention for the participants.

Problem-Solving Lesson 1: The Gestalt Legacy

Learning Questions:

•What do we mean when we talk about 'problem-solving'?

•Why is 'problem-solving' relevant to Humanities students?

•What is the 'Gestalt legacy' and how can it illustrate some of the ways that people perceive problems?

Fig. 3 *The Gestalt Legacy Definitions Handout*

Problem-solving lesson 1: The Gestalt legacy definitions

Problem-solving	when a person has a goal but does not have an immediate solution as to how to achieve it
	Organisation for Economic Co-operation and Development
	a worldwide study by the OECD intended to evaluate educational systems by measuring 15-year-old school pupils' scholastic performance on various areas including problem-solving
	fixedness as the result of a function dissimilar to that demanded
	a tradition within problem-solving research on the visual aspects of problems affecting the perception of the problem (and by extension, the ability to problem-solve)
	requires that nine dots arranged in a square be connected by four straight lines drawn without lifting the pen from the paper and without retracing any lines
The nine-dot problem OECD Gestalt legacy Programme for International Student Assessment (PISA) Functional fixedness	

In this session, the teacher briefly explains the meaning of problem-solving within the context of the research project, referring to the example from the OECD, 2014b "suppose that you have been sending text messages from your mobile phone for several weeks. Today, however, you can't send text messages. You want to try to solve the problem" (p. 370).

The teacher explains that the aim of the project is to *explicitly teach* problem-solving literacy. The teacher reminds the learners of the significance of problem-solving within the academic literature, referring to the OECD, 2019a "modern economies reward individuals not for what they know, but for what they can do with what they know" (p. 3). The teacher then explains the concept of 'functional fixedness' (Duncker, 1945), explaining that whether a sought "object" is found more easily or with more difficulty depends, among other things, on the degree of "fixedness" of the object. Participants are then shown a video illustrating the concept of 'functional fixedness' in the context of solving a problem (National Geographic, 2014). The teacher then explains that an extension of 'functional fixedness' (Duncker, 1945) can be observed when problem-solvers are constrained by principles used in visual perception. Explain to learners that Gestalt psychologists apply the principles used in visual perception to the problem-solving domain, and that visual aspects of a problem affect the perception of the problem (and by extension, the ability to problem-solve) (see Bassock and Novick, 2012).

Participants are then shown the nine-dot problem (Maier, 1930), and have the rules of the problem explained to them. The nine-dot problem is reproduced below.

Fig. 4
The Nine-Dot Problem

After participants have attempted the nine-dot problem, and shared their ideas, participants and teacher then discuss what prevented them from being able to obtain the solution. If the one or more of the participants have managed to solve the nine-dot problem, then they are invited to share the solution with the other participants. If none of the participants have been successful in their problem-solving, the teacher shares a solution to the nine-dot problem. The teachers explains to the participants that academics who have studied problem-solving have observed how the visual perception of a problem affects the ability to problem-solve.

Problem-Solving Lesson 2: Newell and Simon Legacy

Learning questions:

•Recap: What do we mean when we talk about 'problem-solving'?

•What is the 'Newell and Simon legacy' and how can it illustrate some of the ways that people perceive problems?

Fig. 5

Newell and Simon Legacy Definitions Handout

Problem-solving lesson 2: Newell and Simon legacy definitions

Problem-solving	when a person has a goal but does not have an immediate solution as to how to achieve it
	conceptualises problem-solving as a spatial movement that connects the problem-solver's initial state to the goal state
	an approach to problem-solving that employs a practical method that is not guaranteed to be optimal
	an approach to problem-solving that employs a finite sequence of instructions guaranteed to yield the correct solution
	there are three pegs mounted on a base. On the leftmost peg, there are a number of disks of differing sizes. The disks are arranged in order of size with the largest disk on the bottom and the smallest disk on the top. The disks may be moved one at a time, but only the top disk on a peg may be moved, and at no time may a larger disk be placed on a smaller disk. The goal is to move the disk tower from the leftmost peg to the rightmost peg
Tower of Hanoi problem Newell and Simon legacy Heuristic Algorithm	

In this session, the teacher briefly explains the meaning of problem-solving within the context of the research project, as before for Problem-solving lesson 1: The Gestalt legacy. The teacher then explains the concept of Simon's (1978) 'problem space'. The teacher then applies these concepts to a problem-solving example of a simply connected maze, that is one not containing any loops (see Bray, Butscher & Rubinstein-Salzedo, 2021). The teacher explains in these terms:

It has an *initial state* (see 1 on Fig. 5)

It has an *end state* (see 2 on Fig. 5)

It has lots of *in between states* (see 3,4,5,6 on Fig. 5)

It has a *set of operators:* Turn right, Turn left, Go back

In any given *state* there are a number of different *operators* that can be used, and each one will generate a *new state*

There is a whole space of *possible states*, and paths through this space. Only some will lead to the *goal state*

Fig. 6
A simply connected maze

The figure originally presented here cannot be made freely available via ORA because of copyright. The figure was sourced at Tartila. (n.d.). Labyrinth Game Way Square Maze [Digital image]. Shutterstock. https://www.shutterstock.com/image-illustration/labyrinth-game-way-square-maze-simple-161277566

(Tartila, n.d.)

The teacher then goes on to explain that it would be possible to use an algorithm to solve this problem, with one such algorithm being the wall follower. The teacher explains Newell and Simon observed that people's search used heuristics, which reduce the amount of search that is required (Bassock and Novick, 2012). The teacher then describes such Newell and Simon's (1972, p. 416) "means-ends analysis" heuristic. To illustrate this concept, the teacher refers back to the maze problem and identifies a 'subgoal' state such as point 6 on the maze. The teacher then talks through the set of operators that would remove (or reduce) the different between the two states.

Participants are then shown the Tower of Hanoi problem (Lucas, 1891). The version the students are shown is the three-disk, three-peg version. A slightly different version of the tower of Hanoi problem is reproduced below.

Fig. 7
The Five-Disk, Three-Peg Tower of Hanoi

(Hinz, Klavžar and Petr, 2018, p.94)

The problem requires that the disk tower made of (disks of differing sizes) be moved from the left peg, to the right peg. Disks may be moved one at a time, but only the top disk on a peg may be moved, and at no time may a larger disk be placed on a smaller disk (see Hinz, Klavžar and Petr, 2018).

After participants have attempted the Tower of Hanoi problem, and shared their ideas about potential methods of solving the problem, the teacher then shares all possible problems states for the three-disk, three-peg Tower of Hanoi problem (see below).

Fig. 8
All Possible Problem States for the Three-Disk, Three Peg Tower of Hanoi Problem

(Bassok and Novick, 2012, p.416)

The teacher explains that this diagram illustrates initial state (State #1), the goal state (State #27), and all the 'in-between' states which can be considered 'subgoals'. The thicker gray arrows illustrate the shortest (and therefore optimum) solution path. The teacher explains to the participants that academics who have studied problem-solving have identified how people use heuristics in order to reduce the amount of searching in their problem-solving. By using 'subgoals' and navigating from the 'current state', it is possible to reduce the amount of searching in the problem-solving process.

Problem-Solving Lesson 3: Problems Encountered When Engaging With Problem-Solving

Learning questions:

•Recap: What do we mean when we talk about 'problem-solving'?

•What are 'Principles of visual perception' and how can they hinder problem-solving?

•What cognitive behaviours interfere with problem solving?

Fig. 9

Problems Encountered When Engaging with Problem-Solving Definitions Handout

Problem-solving lesson 3: Problems encountered when engaging with problem-solving definitions

Problem-solving	when a person has a goal but does not have an immediate solution as to how to achieve it
	figures with edges that are smooth are more likely seen as continuous than edges that have abrupt or sharp angles
	incapacity to endure the aversive response triggered by the perceived absence of sufficient information, and sustained by the associated perception of uncertainty
	holding the belief that worry is helpful in some way
	when you feel helpless to solve problems, view problems as threatening, or as barriers or obstacles, and doubt your ability to solve problems
	the behaviour of only dealing with problems when absolutely necessary
Poor problem orientation Positive beliefs about worry The Law of Good Continuation Intolerance of uncertainty Cognitive avoidance	

In this session, the teacher briefly explains the meaning of problem-solving within the context of the research project, as before for Problem-solving lesson 1: The Gestalt legacy. Referring back to back to lesson 1, the teacher reminds participants that Gestalt psychologists have shown that various visual aspects of the problem affect how people understand problems and, therefore, generate problem solutions. Participants are then shown four different cladograms showing the evolutionary relationship between different life-forms (see below).

Fig. 10

Four Cladograms Depicting Evolutionary Relationships Among Six Animal Taxa

The figure originally presented here cannot be made freely available via ORA because of copyright. The figure was sourced at Bassock, M. and Novick, L. R. (2012) 'Problem Solving', in Holyoak, K. J. and Morrison, R. G. (eds.)
The Oxford Handbook of Thinking and Reasoning. Oxford: Oxford University Press.
doi:10.1093/oxfordhb/9780199734689.013.0021

(Bassok and Novick, 2012, p.427)

The teacher explains that (a) and (d) are informationally equivalent, but not computationally equivalent. As a consequence, when asked to interpret this information, problem-solvers are more likely to do this accurately when the information is presented as it is in (d), rather than (a) (see, 2012). The teacher explains that this is an example of how visual aspects of the problem affect how people generate problem solutions. As Bassok and Novick (2012) write "the Gestalt principle of good continuation makes the long slanted line at the base of the ladder appear to represent a single hierarchical level" (p.426).

The teacher goes on to explain that Dugas et al. (1998) built a cognitive-behavioural model consisting of four elements (pp.216-217):

1. Intolerance of uncertainty
2. Beliefs about worry
3. Poor problem orientation
4. Cognitive avoidance

The teacher briefly explains each of these, and encourages the participants to monitor themselves when they are problem-solving to see if they exhibit these behaviours.

Research Design

Consideration must now be given as to how to address the above research questions. Edwards and Talbot (1999) provide this definition of practitioner research “any piece of research carried out by a practitioner which has, as its focus, the concerns of that practitioner's profession, can be defined as practitioner research” (p.61). Bloom & Broder (1950) remind us that mental processes, such as that of problem-solving, are a very complex and difficult subject to study.

Computer-Based Assessments (CBA) to Measure Problem-Solving Ability

Discussion surrounding the difficulty and complexity of studying mental processes, such as that of problem-solving, has been part of the published research for the last 70 years (see Bloom & Broder, 1950). Given the importance of the educational measurement of problem-solving skills (see Tóth et al., 2017) it is now necessary to turn to the challenge of measurement.

One obstacle to collecting useful data to measure the process of problem-solving has been that researchers have lacked the means to satisfactorily examine the cognitive process accurately (see Bloom & Broder, 1950). This remains a contemporary issue, observed by Csapó & Funke (2017) who write “educators have few reliable metrics to observe the problem-solving skills of their students” (p. 4).

More recently academics have lent on CBA in order to measure problem-solving. This is reflected in the changes to the methods that the OECD use in their PISA between 2003 and 2012. In 2003 cross-disciplinary problem-solving was assessed through a written test (OECD, 2005), while in 2012 the assessment was delivered through computers (OECD, 2014a). The rationale given was that this allowed students to gather information needed to solve the problem by gathering feedback on the effect of their interventions in a simulated environment. Additionally, the sequence of actions performed by students was contained in a log file. This played a role in how students were scored as it made it possible to identify when students had guessed a correct answer, and not award a correct mark for that answer.

It also allowed insight into the process of problem-solving which later could be analysed. However, it was acknowledged that the students' familiarity with ICT may impact students' performance (OECD, 2014a, pp. 33-34; also see Greiff et al., 2014; Csapó & Funke, 2017). Using CBA to assess the problem-solving of school aged students is an established process (see Schweizer, Wüstenberg & Greiff, 2013; Shute, Moore & Wang, 2015; Shute et al., 2016; Greiff, Krkovic & Hautamäki, 2016).

Greiff et al. (2013) identified that the widespread use of computers and students' familiarity with ICT had reduced barriers to using CBA (see also Prensky, 2001). However, the expertise needed to deliver CBAs remained a significant barrier. To this end, they aimed to create a platform that would make CBA with problem-solving tasks which would be accessible for researchers. The author contacted Professor Funke, formally of Heidelberg University, enquiring about the use of the platform. Professor Funke suggested (J. Funke, personal communication July 6, 2021) contacting Professor Greiff of Luxembourg University. Professor Greiff suggested (S. Grieff, personal communication, July 7, 2021) the use of Complex problem solving test (COMPRO) authored by Greiff & Wüstenberg, published by Schuhfried (see Schuhfried, 2020). Due to a technical constraint, it was not possible to use COMPRO. A representative from Schuhfried instead suggested (D. Brieber, personal communication, January 25, 2021) using Inventory for testing cognitive capabilities (INT). The main variables measured through INT are (a) cognitive ability; (b) logical reasoning; (c) verbal ability (d) numerical ability; (e) visual-spatial ability (Schuhfried, 2019). To avoid overly lengthy CBAs, the test was limited to logical reasoning and visual-spatial ability. An adaptive presentation was chosen, meaning "the test items are adapted to the individual performance level of the person to be tested" (p. 30). INT is implemented through the Vienna Test System (VTS). The use of VTS has been shown to shown to enhance psychology research (see Ong, 2015).

The use of Questionnaires

Check & Schutt (2012) define questionnaires as "survey instrument[s] containing the questions in a self-administered survey" (p. 162). The aim of collecting questionnaire data through computers was to limit the impact on participants' time and lower attrition by allowing students to respond without being bound to a particular place or time. These questionnaires were designed to examine participant's perceptions and attitudes towards problem-solving, and changes in awareness of problem-solving in the classroom.

Mixed Methods

On the topic of methods Denscombe (2017) reminds us that "the use of more than one method can enhance the findings of research by providing a fuller and more complete picture of the thing that is being studied" (p. 163).

The design of a research using more than one method is what Schoonenboom and Johnson (2017, p. 108) refer to as "mixed methods research (MMR) designs". The use of multiple methods to improve the validity of a researcher is known as Triangulation, defined by Denzin (1978, p. 291) as "the combination of methodologies in the study of the same phenomenon." In the context, it is different methods of collecting data which are combine, which Denscombe (2017, p. 168) refers to as "methodological triangulation (between-methods)".

Bryman (1998) reminds us that at the outset, the precise nature of the eventual uses and advantages of combining qualitative and quantitative research may not be known. The true potential of this fusion may only be encountered in fullness of time.

To this end, the two combined methods of collecting data to answer the research questions are

1) Self-administered computer-based assessments conducted through Inventory for testing cognitive capabilities (INT)
2) Self-administered online questionnaires collected though google forms

The advantage of combining these two methods is that they should not contain the same biases (see Maxwell, 1996), as the first method compares results against a representative norm sample (see Schuhfried, 2019), while the second method, the questionnaire, is self-reported. The aim is to avoid systematic biases such as a self-report bias.

The types of data collected by these methods will also differ, with the CBAs generating quantitative data and the questionnaires generating qualitative data. Menter et al. (2011, p. 193) expresses the former of these types as “quantitative data are data expressed in numerical form” (p. 193), while Flick (2007) informs us that

> Qualitative research uses text as empirical material (instead of numbers), starts from the notion of the social construction of realities under study, is interested in the perspectives of participants, in everyday practices and everyday knowledge referring to the issue under study. (p. 2)

Ethical Considerations

In order to ensure that the highest ethical standards were met, I referred to Check and Schutt (2012) who laid out ‘five guidelines’ regarding ethical issues. My research methods were centred around these guidelines:

> 1. Research should cause no harm to subjects.
> 2. Participation in research should be voluntary, and therefore subjects must give their informed consent to participate in the research.
> 3. Researchers should fully disclose their identity.
> 4. Anonymity or confidentiality must be maintained for individual research participants unless it is voluntarily and explicitly waived.
> 5. Benefits from a research project should outweigh any foreseeable risks. (pp. 7-8)

BERA Ethical Guidelines for Educational Research

Denscombe (2017, p. 340) reminds us that Professional research associations publish codes of research ethics that they expect members to abide by. To this end, I cross-referenced my research methods to ensure they satisfied the British Educational Research Association (BERA) Ethical Guidelines for Educational Research (fourth edition). At the beginning of the project it was made explicit to potential participants that participation was optional, and that every effort was being made to ensure the research would not impact learning for their A-level Economics course (beyond any advantages from improvements in problem-solving). This was a conscience acknowledgement of the existing power imbalance between myself as the teacher and researcher, and the students and participants. This formed part of my ethical responsibility to participants with respect to consent, specifically contributing to satisfying BERA guideline 8 “voluntary informed consent to be involved in a study will be obtained at the start of the study” (2018, p. 9) and guideline 19 “the extent to which a researcher’s reflective research into their own practice impinges upon others” (2018, p. 13). All participants were informed that they had the right “to withdraw from the research for any or no reason, and at any time” (2018, p. 18). This contributes to satisfying guideline 31 “Right to withdraw”.

BERA ethical guidelines 9 states

> Researchers should do everything they can to ensure that all potential participants understand, as well as they can, what is involved in a study. They should be told why their participation is necessary, what they will be asked to do, what will happen to the information they provide, how that information will be used and how and to whom it will be reported (2018, p. 15)

In order to work within this guideline, when introducing the research project to potential participants time was taken to explain to the students about the nature and purpose of the research project, and what would be required from them if they chose to participate.

In accordance with guideline 33 “Incentives” (2018, p. 19) I acknowledge that I used incentives to encourage participation in my research. These were limited to biscuits which were both made available to participants during the scheduled sessions, and which participants could take away with them at the end of the sessions. I am satisfied that this incentive did not “impinge on the free decision to participate” (2018, p. 19). Biscuits were presented in their original supermarket packaging which listed allergens in accordance with the EU Food Information for Consumers Regulation (2011), and listed ingredients in accordance with The Food Information Regulations (2014) legislation. This was an active choice, in the spirit of guideline 35 “Researchers should make known to the participants … any predictable … harm potentially arising from the process … of the research” (2018, p. 19), and, pertaining to religious dietary prohibitions, in the spirit of guideline 1 “Individuals should be treated fairly, sensitively, and with dignity and freedom from prejudice, in recognition of both their rights and of differences arising from … faith”.

BERA ethical guideline 36 states “… minimise the effects of research designs that advantage or are perceived to advantage one group of participants over others” (2018, p. 20). It was with the duty to uphold this guideline that the decision to use two comparison groups was made, allowing all participants to gain the potential benefit of the intervention.

BERA ethical guidelines 40 – 51 outline the best ethical practice with respect to “Privacy and data storage” (2018, pp. 21-26). To work within these guidelines, measures were taken to ensure that participants’ data was treated confidentially and anonymously. All personal data was protected with the strictest adherence to the Data Protection Act (2018).

In particular these were used to inform these methods with respect to participants’ privacy and storing sensitive data (pp. 21-26). In addition to this, all participants were informed that the privacy and confidentially of their information was guaranteed.

Central University Research Ethics Committee (CUREC)

Drawing upon the work of Denscombe (2017) who writes “the importance attached to research ethics is evident in the fact that social researchers will normally need to get prior approval for their investigation from an *Ethics Committee”* (p. 337, italics in original).

I applied for ethical approval for my research project from the Central University Research Ethics Committee (CUREC). Formal consent from the headteacher of the school where the research project was based was also obtained (see appendix B) This consent was obtained in loco parentis as the school operates with the highest ethical standards, so the formal consent of individual parents or staff was not necessary. The research project did not begin until ethical approval from CUREC and the headteacher was granted. This was in accordance with, and in order to satisfy, the University of Oxford’s ethical standards of research.

Collaboration

Academics such as Coleman, Lumby and Middlewood (1999) have elucidated about the shortcomings in practitioner research in having positive impact writing “all these criticisms have in common the fear that current research, for whatever reason, does not appear to ‘make a difference’ to practice and thereby improving standards” (p. x).

Other authors such as Bassey (1998) have observed that the weakness in educational practitioner research comes from insufficient communication of results to other practitioners.

Hillage et al.’s (1998) review of educational research concluded that the perception of teachers is that most research into education doesn’t have a large impact on their classroom practice, and goes on to give the following warning “the conclusions and implications of much research are not reaching their intended audience and those who could benefit from it” (p.51).

To avoid reproducing these weaknesses, a Continuing Professional Development (CPD) session explaining the main findings of the research and its impact will be delivered to colleagues. This session will have an aim to demonstrate to teaching staff how problem-solving literacy can be integrated into lessons.

Findings and Discussion

The following data was collected from the following two sources:

1) self-administered computer-based assessments, *n* = 50.

CBAs administered through the Vienna Test System version 8, using the test label INT version 54.

2) Self-administered online questionnaires, *n* = 5.

Questionnaires collected though google forms

Results

The data collected through the CBAs was quantitative in nature, whereas the data collected through the questionnaires was qualitative in nature. Owing to these differences, the results from both sources are discussed separately below.

CBAs: Main Variables

The data collected through the CBAs was percentile rank (PR) of the two main variables (a) Logical reasoning, and (b) Visual-spatial ability. The PR was generated against a representative norm sample (*n* = 387) (Schuhfried, 2019). If a participate achieves a PR of 64, this means that 64% of the people in the norm sample were equal or worse with respect to the relevant variable, and 36% equal or better.

Data Checks: Outliers and Normality of Distribution

As not all participants completed all CBAs, there were gaps in the dataset. These gaps were missing not at random (MNAR) in nature (Qin, 2017). In order to address the missing data, the last observation carried forward (LOCF) measure was used, imputing the data with the last observed value (see Jackson et al., 2014). The data was checked for outliers and non-normal distribution. To assess the data for outliers, probability–probability plots (P-P plots) of the results were generated. Examining the P-P plots, no obvious outliers were observed. Further investigation of the data in order to identify outliers was conducted by examining *z*-scores. Field (2009, p. 102) offers criteria by which to compare *z*-scores to identify if data is normally distributed. Using Field's criteria, it was identified that there was one participant who stood out as a significant outlier in the data. To reduce the impact of this outlier, the participant was removed from the data set, (*n* = 23). After removing the participant, *z*-scores were checked again and now meet Field's criteria.

Table of CBA Participant Demographics

A table summarising the demographics of the different comparison groups is shown below.

Table 4

CBA Participant Demographics

	Group A	Group B	Total
No of males	7	5	
No of females	5	6	
Total	12	11	23
No of Y12s	9	5	
No of Y13s	3	6	
Total	12	11	23

Table 5

Lesson Attendance and CBA Completion by Comparison Group

	Group A	Group B	Total
Problem-solving lesson attendance			
No of attendees to PS lesson 1	4	3	
No of attendees to PS lesson 2	5	2	
No of attendees to PS lesson 3	6	4	
Total	15	9	24
CBAs completion			
No of 1st CBAs completed	11	12	
No of 2nd CBAs completed	9	9	
No of 3rd CBAs completed	5	4	
Total	25	25	50

Analysis of Relationships Between the Data: Independent-Samples T Test

The data was then checked for the relationship between the change in logical reasoning PR, and visual-spatial ability PR against a range of different dependant variables. These dependant variables were Gender (Male, Female), Comparison group (Group A, Group B) and Year group (Year 12, Year 13). Two-Sided *P* values were used to check for significance. In each case the data was checked for homogeneity of variance using Levene's test, and the relevant *t* value, degrees of freedom, and Two-Sided *P* value was used depending on the equal variance being assumed or the equal variance being not assumed. The results are reported below.

Gender. On average, participants experienced greater change in their logical reasoning PR if they were female (M = 9.33, SE = 5.925) than if they were male (M = 8.59, SE = 5.955). This difference was not significant t(22) = −.70, p > .05; and represented a small-sized effect r = .151. On average, participants experienced greater change in their visual-spatial ability PR if they were male (M = 11.06, SE = 5.9885) than if they were female (M = .33, SE = 8.542). This difference was not significant t(22) = −.947, p > .05; and represented a small-sized effect r = .202.

Comparison Group. On average, participants experienced greater change in their logical reasoning PR if they were in group A (*M* = 10.27, *SE* = 5.985) than if they were in group B (*M* = 7.42, *SE* = 7.131). This difference was not significant *t*(22) = .304, *p* > .05; and represented a small-sized effect *r* = .066. On average, participants experienced greater change in their visual-spatial ability PR if they were in group B (*M* = 8.75, *SE* = 4.514) than if they were in group A (*M* = 7.73, *SE* = 9.418). This difference was significant *t*(22) = −.98, *p* < .05; and represented a small-sized effect *r* = .209.

Year Group. On average, participants experienced greater change in their logical reasoning PR if they were in year 12 (*M* = 10.07, *SE* = 6.944) than if they were in year 13 (*M* = 6.78, *SE* = 5.090). This difference was not significant *t*(22) = .342, *p* > .05; and represented a small-sized effect *r* = .074. On average, participants experienced greater change in their visual-spatial ability PR if they were in year 13 (*M* = 8.44, *SE* = 4.035) than if they were in year 12 (*M* = 8.14, *SE* = 7.873). This difference was significant *t*(22) = −.034, *p* < .05; and represented a small-sized effect *r* = .078.

Analysis of Relationships Between the Data: Bivariate Correlations

Next, the data was examined using Pearson’s product-moment correlation coefficient (see Field, 2009). One-Sided *P* values were used to check for significance.

Correlation Between Number of Problem-Solving Lessons Attended and Logical Reasoning PR on the Third CBA. The data was then checked using a bivariate correlation to examine the relationship between the in logical reasoning PR scores during the CBA 3, and the number of problem-solving lessons attended. The data suggests there is a positive correlation between the number of problem-solving lessons attended and the logical reasoning PR score in the third CBA. This correlation was significant ($r = .616$, $p < .05$). Due to the size of the dataset ($n = 9$), this relationship was not investigated further using a regression analysis.

Correlation Between Number of Problem-Solving Lessons Attended and Visual-Spatial Ability PR on the Third CBA. The data was then checked using a bivariate correlation to examine the relationship between the in visual-spatial ability PR scores during the CBA 3, and the number of problem-solving lessons attended. The data suggests there is a positive correlation between the number of problem-solving lessons attended and the visual-spatial ability PR score in the third CBA. This correlation was not significant ($r = .255$, $p > .05$). Due to the size of the dataset ($n = 9$), this relationship was not investigated further using a regression analysis.

Questionnaires: Main Variables

The online questionnaire was designed to gauge participant's perception and attitudes towards problem-solving, as well as gauging any changes in awareness of problem-solving in the classroom. A full reproduction of the online questionnaire as it would be seen participants is included in the appendix (see appendix A).

Table of Questionnaire Participant Demographics

A table summarising the demographics of the questionnaire respondents is shown below, $n = 5$.

Table 6

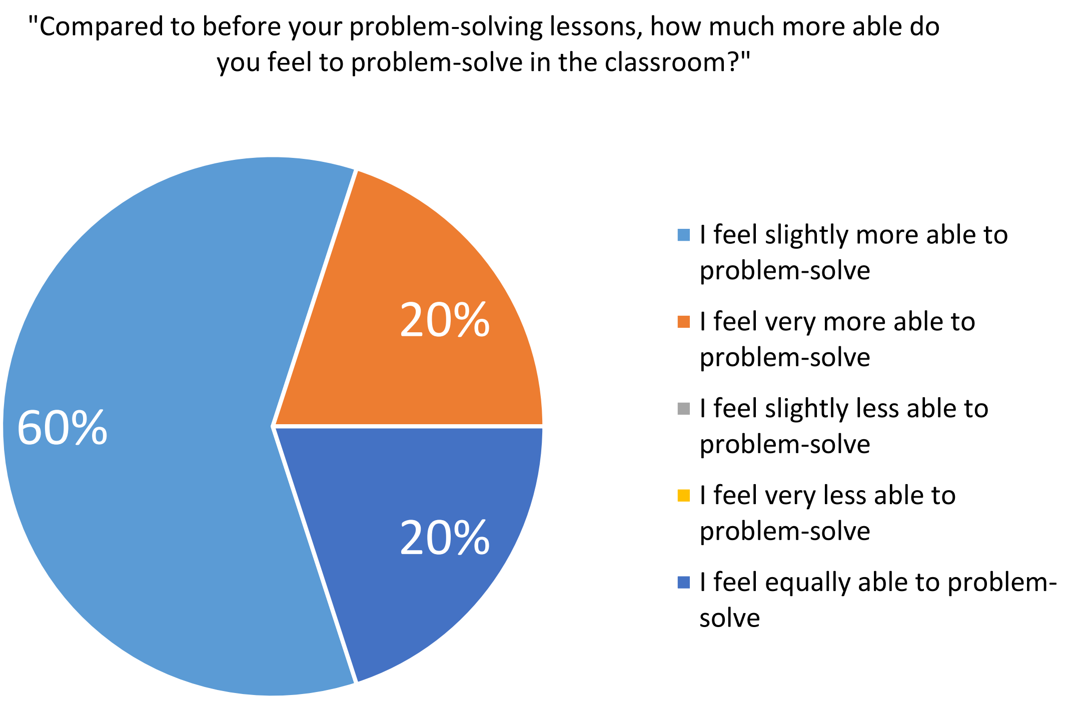
Questionnaire Participant Demographics

	Group A	Group B	Total
No of males	3	2	
No of females	0	0	
Total	3	2	5
No of Y12s	3	2	
No of Y13s	0	0	
Total	3	2	5

Analysis of Results From Questionnaire

The responses to the multiple-choice question *Which one of the following statements would you consider to be the most accurate answer to the question "Compared to before your problem-solving lessons, how much more able do you feel to problem-solve in the classroom?"* are summarised in Fig. 11 below

Fig. 11
Changes in Attitude Towards Problem-Solving



Discussion

The following section discusses the results in order to address the respective research questions (RQs) suggested for this study in the method section.

Research Question 1

RQ1 is framed as a hypothesis.

H_0: Teaching problem-solving literacy to learners does not result in statistically significant better problem-solving aptitude as measured through computer-based assessments.

H_A: Teaching problem-solving literacy to learners results in statistically significant better problem-solving aptitude as measured through computer-based assessments.

Data from the CBAs showed a statistically significant correlation between attending problem-solving lessons and problem-solving aptitude as measured through the logical reasoning variable. For this reason, the null hypothesis (H_0) can be rejected. The data supports the alternative hypotheses (H_A). Given that that there was not a statistically significant correlation between attending problem-solving lessons and problem-solving aptitude as measured through the visual-spatial ability variable, the data suggests that the nature of the problem-solving lessons impacted only some aspects of problem-solving while neglecting others.

Research Question 2

Does gender, year group, or membership of a specific comparison group significantly impact changes in problem-solving ability?

Data from the CBAs did not show any statistically significant correlation between the change participants' problem-solving ability measured through either the logical reasoning variable or through the visual-spatial ability variable, and gender.

Data from the CBAs did not show any statistically significant correlation between the change in participants' problem-solving ability measured through the logical reasoning variable, and comparison group. Data from the CBAs did show a statistically significant correlation between correlation between the change in participants' problem-solving ability measured through the visual-spatial ability variable and comparison group, showing that participants experienced greater change in the visual-spatial ability variable if they were in group B rather than group A. This was a small-sized effect.

Data from the CBAs did not show any statistically significant correlation between the change in participants' problem-solving ability measured through the logical reasoning variable, and year group. Data from the CBAs did show a statistically significant correlation between correlation between the change in participants' problem-solving ability measured through the visual-spatial ability variable and year group, showing that participants experienced greater change in the visual-spatial ability variable if they were in year 13 rather than year 12. This was a small-sized effect.

The data did not identify any medium or large sized effects on logical reasoning PR and visual-spatial ability PR as caused by gender, comparison group, or year group. This data only indicated trends, and so no causal relationships can be inferred. As the effects were all shown to be small-sized it can be concluded that gender, year group, or membership of a specific comparison group did not significantly impact changes in problem-solving ability. If a methodological bias in the way the intervention was delivered was present, it did not significantly affect the results of the data. As there was a statistically significant relationship between attending problem-solving lessons and problem-solving aptitude, and no medium or large-sized effect from gender, year group, or comparison group this suggests that improvement in problem-solving ability is more likely to be the result of becoming literate in problem-solving, rather than being the result of other variables.

Research Question 3

How does the teaching of problem-solving affect students' attitude towards problem-solving?

Referring to the responses listed in Fig. 11, there has been general improvement in students' perceptions of their problem-solving ability. No respondent felt that their problem-solving ability had worsened over the course of the research. One respondent felt that they were equally able to problem-solve, while all the other respondents felt either very more able to problem-solve or slightly more able to problem-solve. Given the conclusions made by Bloom & Broder (1950) about the students' confidence in their ability to problem-solve, this improvement in students' perceptions this represents a positive impact of the research project. Therefore, it can be tentatively concluded that the teaching or problem-solving ability contributes generally to forming a more positive attitude towards problem-solving.

Interrogation of the questionnaire data reveals a more textured insight. The respondent who responded that they were equally able to problem-solve responded to the question *Please describe any situations where you have identified problem-solving taking place in a classroom since your problem-solving lessons. Give as many or few examples as you wish.* with "don[']t know". As this participant struggled to identify when problem-solving was taking place, it is perhaps unsurprising that they did not feel any more able to problem-solve. In response to the question *Please describe your impression of problem-solving following my introductory explanation. You don't have to be complimentary or kind! Give as much or as little detail as you wish.* they wrote "not useful to me". This individual attended one of the three problem-solving lessons.

The respondent who answered that they felt very more able to problem-solve answered the question *Please describe any situations where you have identified problem-solving taking place in a classroom since your problem-solving lessons. Give as many or few examples as you wish.* with "MCQ". As this participant identified a specific kind of assessment question for their A-level subject (AQA, 2022) as characterising problem-solving, this may provide some explanation as to their improved belief in their ability. Triangulating this data with the participant's logical reasoning PR and visual-spatial PR revealed that this student did not achieve a PR greater than 1 for any test variable across all of the CBAs. Additionally, this individual took approximately 9 days to complete their initial CBA. This suggests that they started the assessment only to abandon it before finally returning to complete it. This particular participant stood out as a significant outlier in the data and was removed from the dataset before any statistical analysis was performed. This individual attended zero of the three problem-solving lessons. It is therefore apparent that this improvement in their perceived ability was not correlated with assimilating problem-solving literacy, nor with an improvement in the scores of test variables. This finding highlights the usefulness of mixed methods research design.

Table 7

Integrated Results Table of Quantitative and Qualitative Results

Quantitative results	Qualitative results	Example quote [Giving examples of classroom problem-solving]
Attendance to more problem-solving lessons correlated with greater improvement in problem-solving ability	When participants felt equally able to problem-solve, they were less able to identify problem-solving in the classroom	Participant 3: “dont know”
Attendance to fewer problem-solving lessons correlated with smaller improvement in problem-solving ability	When participants more able to problem-solve, they were more able to identify problem-solving in the classroom	Participant 2: “MCQ”

Therefore, the previous tentative conclusion can be refined; the use of CBA to assess problem-solving ability contributes generally to forming a more positive attitude towards problem-solving, irrespective of any change in actual problem-solving ability.

Another theme that emerged from the data, that was not anticipated, was participants identifying and referring to problem-solving in subjects outside of humanities. In response to the question *Please describe any situations where you have identified problem-solving taking place in a classroom since your problem-solving lessons. Give as many or few examples as you wish.* answers such as “Maths and Physics lessons” and “There are obvious examples of problem solving in terms of subjects such as maths where the entire subject is to solve specific subject problems. … There are also coursework subjects such as DT where the goal of the project is to solve a problem that one identifies themselves, often one that requires research" illustrated that participants were able to identify problem-solving taking place across a range subjects.

Limitations

The research suggests a positive correlation between cognitive ability scores and attending problem-solving lessons, indicative of a trend. However, the sample size prohibited any causal relationship to be established. Given that it was insufficiently powered for a statistical analysis, it would be prudent to use this as a precursor to future research. Future studies should ensure a sufficiently large sample size in order to generate statistically significant analysis. Future researchers in this field may wish to investigate the possibility of a causal relationship.

A potential issue impacting the data quality was the participants' attendance rate to problem-solving lessons. Across the two comparison groups, attendance across all three problem-solving lessons was as follows (all figures are rounded to nearest percent):

Group A: 42%

Group B: 25%

Across all groups: 33%

Future researchers may wish to improve attendance, and so improve the rigour of the results.

Another potential issue impacting the data quality was the participants' completion rate of problem-solving CBAs. Across the two comparison groups, completion across all three CBAs was as follows (all figures are rounded to nearest percent):

Group A: 78%

Group B: 69%

Across all groups: 74%

Future researchers may wish to improve the CBA completion rate, and so improve the rigour of the results.

A potential issue limiting the impact of the interventions is the what Norman (1980) refers to as “folk psychology”. This is the implicit model of the mind that is determined by the culture that people live in, which plays a role in how people study and how they learn. Norman contends that such conceptions of how the mind work are likely to be inaccurate and misleading (p. 99). Pre-conceived notions about how learning takes place may act as a barrier to assimilating new conceptions about learning, hindering the effectiveness of problem-solving literacy.

The variables used to measure problem-solving aptitude do not precisely distinguish between general intelligence and problem-solving cognitive ability, despite constituting different constructs (see Danner et al., 2011a). Drawing upon the Danner et al.’s (2011b) analysis of reliability and validity of a problem-solving CBA, the use of two of the main variables that INT is able to measure is not sufficient to be content-valid performance measures (see Dörner, 1980).

Conclusion and Next Steps

First, I will briefly summarise the results obtained collected. Secondly, I will highlight some potential areas of interest for future research. Thirdly, I will outline the implications of these findings on classroom practice. Fourthly, I will make a number of acknowledgements. Finally, I will make a concluding remark to the research and development project.

Summary

These results tentatively suggest a positive effect on both learners’ ability and attitude towards problem-solving as caused by an intervention based on explicitly teaching problem-solving literacy. The effect on learners’ ability is more significant than the effect of learners’ gender, year group, or comparison group. This suggests that problem-solving is an aspect of learning which can be addressed and targeted within classroom practice. The results very tentatively suggest that teaching problem-solving literacy within the context of humanities lessons may also have a positive spill over effect on learners engaged in problem-solving in subjects belonging to other domains. Although results of this project do exhibit some methodological weaknesses, they could serve as guidance for future research on the contents of problem-solving literacy, the delivery of problem-solving literacy, assessing changes in problem-solving ability, and assessing changes in learners' attitudes towards problem-solving.

Future Research

The research suggests a positive correlation between cognitive ability scores and attending problem-solving lessons, indicative of a trend. However, the sample size prohibited any causal relationship to be established. Given that it was insufficiently powered for a statistical analysis, it would be prudent to use this as a precursor to future research. Future studies should ensure a sufficiently large sample size in order to generate statistically significant analysis. Future researchers in this field may wish to investigate the possibility of a causal relationship.

Future researchers may wish to examine the content of the problem-solving lessons in order to determine which measurable aspects of problem-solving ability can be affected through attending problem-solving lessons.

No previous studies using INT have ever been published (D. Brieber, personal communication, August 29, 2022), making this amongst the first academic studies to be conducted using the INT software. It therefore lacks any obvious studies to which it can be compared to evaluate the usefulness of INT as method of CBA. However, this research could form the basis for future research using INT with school students as participants. Although this project has focused on humanities subjects, there is no obvious barrier to the project being repeated in other subject areas as well. CBA using the VTS has been used as a measuring tool in sport psychology research.

Implications for Classroom Practice

I have demonstrated that it is possible to 'teach' the literacy of problem-solving. Within my classroom practice, these results indicate the importance of explicitly teaching problem-solving literacy as part of my subject teaching. I will model problem-solving in a salient way, referring to the elements of problem-solving literacy highlighted in this project. Where I encounter barriers in my own problem-solving when modelling problem-solving I will articulate these barriers to the learners. I will explicitly signpost examples of problem-solving activities across all subjects that I teach. I will emphasise process over product, and challenge learners' attitudes towards problem-solving when it appears to hinder the problem-solving process. I will explain to learners that expectations of school-leavers have increasingly been more demanding of their problem-solving ability. I will explain to learners that decision-making measures provide predictive insights into aspects of professional success, beyond what can be measured through general intelligence (see Danner et al., 2011b).

Although this project has focused on humanities subjects, this limitation was self-imposed as I am situated within the humanities faculty. I posit that the research undertaken in this project has value for teachers of other subjects as well. The findings of this research will be shared with my teaching colleagues at my current school.

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Concluding Remarks

Greiff et al. (2013) argue for the use of assessment CBA platforms in learning environments, writing

> In pursuit of optimizing education, we argue that assessment platforms could be used as learning environments. Specifically designed tasks may be used to assess students' domain-specific problem solving skills with specific contents (e.g., a simple physics or chemistry experiment) or on

> a more general level (e.g., finding a fault in a malfunctioning technical device) (p. 418).

It is in the spirit of their work in the pursuit of optimising education that this research was conducted. Through the process of conducting this research and development project, I have not only changed my own practice, but also gained an understanding of educational psychology.

I imagine myself back in the situation described in the introduction, observing learners in the process of trying to complete classroom problem-solving and encountering a barrier. I like to imagine how the scenario could have played out differently if the learners were equipped with problem-solving literacy.

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Appendix

Appendix A – Online questionnaire

Distance covered in problem-solving

Thank you very much for taking the time to complete this questionnaire.

*Required

Email *

Your email address

What is your name? (This is only for me; your name will not be shared and will not be included in any publication) *

Your answer

Which year group are you in (year 12 or year 13)? *

- Year 12
- Year 13

Which problem-solving group are you in (group A or group B)? (Don't worry too much if you can't remember) *

- Group A
- Group B
- I can't remember

What I mean by 'Problem-solving'

I am going to ask you some questions about problem-solving in the classroom. For the purposes of this questionnaire, I will use the OECD definition of a problem, which is "existing when a person has a goal but does not have an immediate solution as to how to achieve it."

Please describe your impression of problem-solving following my introductory explanation. You don't have to be complimentary or kind! Give as much or as little detail as you wish.

Your answer

Please describe any situations where you have identified problem-solving taking place in a classroom since your problem-solving lessons. Give as many or few examples as you wish.

Your answer

Please describe any classroom situations where you have identified yourself recognising any of the elements of problem-solving that we discussed in the problem-solving lessons. As a reminder, the three problem-solving lessons were 1) Gestalt legacy 2) Newell and Simon legacy 3) Problems encountered when engaging with problem-solving. Give as many or few examples as you wish.

Your answer

Which one of the following statements would you consider to be the most accurate answer to the question "Compared to before your problem-solving lesson how much more able do you feel to problem-solve in the classroom?" *

- I feel very more able to problem-solve
- I feel slightly more able to problem-solve
- I feel slightly less able to problem-solve
- I feel very less able to problem-solve
- I feel equally able to problem-solve

This space is for you to write any additional questions, comments, criticisms, or compliments you might have.

Your answer

Send me a copy of my responses.

Appendix B – Sample of Letter to the Head Teacher

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Director Professor Jo-Anne Baird

Head Teacher
School, Address
15 January 2022

Dear ____________,

I am writing to enquire about conducting research in school this academic year. As you know, I am studying for the Master's in Learning and Teaching at Oxford University, supervised by ____________. In my final research project *"Can an intervention based on explicitly teaching problem-solving literacy affect problem-solving aptitude and engagement of students in humanities subjects?"* I will explore the problem-solving efficacy of sixth form Economics students, and if this can be improved through intervention.

The research will take place with two sixth form Economics classes (Y12 and Y13) working towards A-level Economics. I am hoping to develop ways of helping students to think about the process of problem-solving, and to have them be able to identify and act upon their own barriers to problem-solving. My research focus is on imparting problem-solving literacy on to students, and seeing if it impacts their problem-solving aptitude.

By participating in the research, the school would be contributing to a project that will deepen our understanding of how students relate to problem-solving, and so contribute towards developing ways of coaching students' problem-solving.

I hope to conduct this research between January 2022 and April 2022. I would be observing students, taking notes, and using a piece of software called INT in order to assess learner's problem-solving ability.

Oxford University has strict ethical procedures on conducting ethical research, consistent with current British Educational Research Association guidelines. The University also recognises, however, that my study is a piece of practitioner research, and that schools already operate with the highest ethical standards. Therefore only your formal consent as headteacher is necessary, and not that of individual parents or staff. However, throughout the research, students and other teachers will be able to refuse to participate in any research activities at any time.

All participants, including students, teacher and the school, would be made anonymous in all research reports. The data collected would be kept strictly confidential, available only to my supervisor ____________ ____________@education.ox.ac.uk and me, and only used for academic purposes. It will be kept for as long as it has academic value.

If you are happy for me to proceed with this study, please confirm that using the attached reply form. If you have any concerns or need more information about what is involved, please contact me or my supervisor. Further, if you have any questions about this ethics process at any time, please contact the chair of the department's research ethics committee, though: research.office@education.ox.ac.uk

I look forward to hearing from you.

Yours sincerely,

Appendix C – SPSS syntax

```
DATASET ACTIVATE DataSet1.
*analyse->compare means->independent samples t-test.
T-TEST GROUPS=Sex(1 2)
 /MISSING=ANALYSIS
 /VARIABLES=LRchangebetween13 VSAchangebetween13
 /ES DISPLAY(TRUE)
 /CRITERIA=CI(.95).

T-TEST GROUPS=Group(1 2)
 /MISSING=ANALYSIS
 /VARIABLES=LRchangebetween13 VSAchangebetween13
 /ES DISPLAY(TRUE)
 /CRITERIA=CI(.95).

T-TEST GROUPS=YearGroup(1 2)
 /MISSING=ANALYSIS
 /VARIABLES=LRchangebetween13 VSAchangebetween13
 /ES DISPLAY(TRUE)
 /CRITERIA=CI(.95).

*Bivariate correlations
CORRELATIONS
 /VARIABLES=NOLESSONS LRPR_T1 LRPR_T2 LRPR_T3
 /PRINT=ONETAIL NOSIG FULL
 /CI CILEVEL(95)
 /MISSING=PAIRWISE.

CORRELATIONS
 /VARIABLES=NOLESSONS VSAPR_T1 VSAPR_T2 VSAPR_T3
 /PRINT=ONETAIL NOSIG FULL
 /CI CILEVEL(95)
 /MISSING=PAIRWISE.
```