Framing Word Problems: Task Confidence in Early Childhood Pre-service Teachers

Luke Brownlow

Flinders University, Adelaide, Australia

luke.brownlow@flinders.edu.au

Abstract: *There is significant research addressing identities in mathematics focusing on school children and maximizing testing scores. However, mathematics confidence in pre-service teachers is something that needs further attention as they will have foundational roles in students developing lifelong mathematics identities. Hence, mathematics confidence in pre-service teachers is the focus of this research set around word problems. Beyond this context, the study is inspired by the framing effect and its ability to alter perceptions with gain and loss discourse that frames the logical information presented. 80 early childhood pre-service teachers completed a survey and rated their pre-task and post-task confidence levels on a series of framed word problems. This method revealed that the framing effect had a negligible impact on task confidence with all frames increasing task confidence to similar levels.*

Introduction

This study is set around mathematics task confidence in early childhood pre-service teachers (PSTs) against the backdrop of task manipulation in mathematics. Specifically, manipulation through the framing effect to present word problems to have loss, gain, or neutral frames then measuring for differences in task confidence. Manipulation of tasks in mathematics is recognized to have considerable cognitive effects (Sparks & Ledgerwood, 2017). The measurement of these considerable effects seldom considers concepts around mathematics confidence (Ledgerwood & Boydstun, 2014), instead opting for contributing to performance output (e.g., Lowrie et al., 2012). This lack of understanding leaves potential for new development into how task manipulation can alter mathematics confidence. This study seeks to extend research by Lane and Reyes (2019) into the effects of framing on university student performance by looking at a group of future mathematics teachers known for low mathematics confidence, early childhood PSTs. Building upon our understanding of teacher attitudes and self-perceptions is important because of how these factors drive PSTs to adopt positivist teaching approaches and foster affirmative classroom

environments (Kartal, 2020). Research shows that while secondary school PSTs believe that mathematics develops cognitive skills and fosters positive mathematics attitudes (López-López et al., 2021), primary school PSTs have less positive mathematics attitudes than their secondary counterparts (Yildiz et al., 2020) and lesser perceived mathematic identities (Haciömeroğlu, 2020). Sweeting (2011) has identified that early-childhood PSTs have poor relationships with mathematics which is underrepresented in research. This is concerning considering how children's lifelong mathematics attitudes are influenced by teachers (Mensah et al., 2013) and PSTs (Philippou & Christou, 1998). Furthermore, research shows teaching methods are influenced by mathematics attitude for both teachers (Kartal, 2020; Wilkins, 2002) and PSTs (White et al., 2005). Therefore, this study is motivated by the question, do manipulated word problems with frames influence mathematics confidence in early childhood PSTs?

Background

Word Problems

Manipulating Word Problems

Previous research shows how frames impact the way people respond to mathematics (Kaczmarek et al., 2018; Sparks & Ledgerwood, 2017). This study seeks to expand the previously mentioned studies into how frames can impact mathematics task confidence. If frames impact early childhood PSTs' confidence in solving word problems, it may well impact their confidence in teaching them and by extension, students' ability to solve word problems. Seen as the bridge between classroom mathematics and using mathematics in the real world, instruction and self-strategies for word problems is prominent in mathematics research (Kingsdorf & Krawec, 2016). Early research by Pólya (1945) into word problem strategizing sparked decades of development of more systematic instruction in the area (Powell, 2011). As a result, a significant body of literature has been built around using and teaching schemas for word problem solving (see Fuchs et al., 2004; Griffin & Jitendra, 2009; Pérez Ariza, 2020). One noteworthy study into manipulation of questions in the Australian schools National Assessment Program – Literacy and Numeracy (NAPLAN) focused on modifying the graphics that accompanied questions (Lowrie et al., 2012). Lowrie et al. (2012) found that even minimal changes or removing graphics can increase understanding and success. Moreover, the observability of key information in these test questions is a factor when manipulation occurs.

Information Salience

Information salience has profound effects on students' ability to solve word problems. With school children, the salience of key information in a task impacts both cognition (Aulet & Lourenco, 2021) and performance (Al-Atrash et al., 2020). Ng et al. (1999) recognized how students can easily solve a problem correctly when given only figures to calculate. Yet, the addition of a few words around the figures causes the success rate to drop as it weakens the salience of key information. For example, *19 people get off a train at the first stop, then 17 people get on the train*

at the second stop. Now there are 63 people on the train. How many were on the train to begin with? This can be easily reduced to an equation, 63-17+19=65. The noise around the figures makes them less salient and increases difficulty. Early research by Jerman and Rees (1972) found that linguistic features, such as number of words and arithmetic operations, impact success despite mathematical equivalency or perceived difficulty. Beyond mathematical ability, reading skills play a big part – poor readers are less skilled at word problems (Jerman & Rees, 1972). Early research found that despite having the skills to solve visual mathematics, many students lacked the comprehension skills to solve auditory word problems because key information was masked (Jerman & Mirman, 1974). More recent research shows students with strong arithmetic skills perform well in solving world problems despite low text comprehension skills (Fuchs et al., 2018). However, strong text comprehension does not compensate for poor arithmetic skills (Pongsakdi et al., 2020). Moreover, competencies in both mathematics and reading are required to solve highly complex word problems (Pongsakdi et al., 2020). These studies demonstrate that if numbers are too salient then the words are overlooked, and if the numbers are too well-hidden, then a lack of linguistic comprehension skills makes the problem too difficult. With this in mind, this study employs the framing effect to modify the words that shelter numbers in word problems whilst keeping difficulty consistent through word count and number of arithmetic operations in the problems.

Framing Word problems

The Framing Effect

Manipulation of word problems was achieved through the framing effect. The framing effect is a glass-half-full versus glass-half-empty approach to human perceptions (Holleman & Maat, 2021). In word problems, Ledgerwood and Boydstun (2014) explained that individuals can be swayed more by words used than numbers. For example, someone browsing headlines might see one article that frames the job market in terms of gains (e.g., 90% employment) and a different article using losses (e.g., 10% unemployment) but be more swayed by one (Ledgerwood & Boydstun, 2014, p. 376). If this demonstrates a change job market confidence, does this approach cause a change in task confidence for word problems? The ground-breaking research on frames comes from Prospect Theory, a behavioural economic theory which details how people make probabilistic choices based on the values of losses and gains rather than the outcome (Tversky & Kahneman, 1979). Prospect Theory is used in education research in both student (Coffey et al., 2020) and teacher (Pusey, 2020) studies. It argues that loss is a stronger motivator than equal gain, but not all losses are weighted equality and context is a relevant factor (Thomas & Nguyen, 2020). Despite context, we avoid risky choices because humans are loss averse (Walasek & Stewart, 2021). For instance, Romanowich and Lamb (2013) showed that framing smoking cessation incentives as losses is most effective. A common application of loss aversion in research is where the description of a person or situation is given using figures of success or figures of failure. For example, surgeries are considered more favourably by patients if they are described using success rates over

failure rates (Marteau, 1989), and shoppers prefer 75% lean meat over 25% fat (Liu et al., 2019). Studies across disciplines show that evaluations were more positive when described using success rates over failure rates (Kreiner & Gamliel, 2018) (see Levin et al., 1998; Pryor & Reeder, 2015 for examples). This led to subsequent research focusing on how a single frame impacts a single judgement and perception (Ledgerwood & Boydstun, 2014). This study extends this perception into the realm of framing word problems to observe variances in confidence when situations are framed.

Frames and Processing Information

When faced with issues of morality, people are not as vulnerable to the impacts of frames. It seems that moral decision making can negate the framing effect (Liu & Liao, 2020; Yang et al., 2021). Furthermore, topics where people have a personal involvement, for example, are less susceptible to frames (Levin et al., 1998), e.g., personal abortion (Marteau, 1989). Although, Marteau (1989) suggests that this may have a connection to strongly held moral beliefs over other factors. Levin et al. (1988, p. 520) found people perceived a 65% cheating rate to be worse than a 35% non-cheating rate in school. However, when participants evaluated their own cheating, they were more logical (Levin et al., 1988, p. 520). The study by Ledgerwood and Boydstun (2014) was conducted outside of a moral scope and showed how frames trigger our inherent biases which affects speed and accuracy in solving word problems. For this study too, there was no moral scope. Furthermore, inherent biases of the participants must be controlled, most notably, negativity bias.

Negativity Bias

Negativity bias is a natural human condition whereby individuals give a greater weight to the negative over the positive based on bias, predispositions, and experience. Despite an innate favouritism for positively framed information, people attribute it less power (Nam et al., 2021). We also tend to make riskier choices for negative frames compared to our choices for equivalent positive frames (Manzoor et al., 2021). Rozin and Royzman (2001) recognize the contagiousness of negativity on the human scale where 200 million Hindu people are deemed untouchable due a caste system. Higher castes are easily contaminated by lower castes; however, there is no reverse effect (Hejmadi et al., 2004). Holiness is another example whereby years of dedication and high status can be immediately undone with a single immoral act (Rozin & Royzman, 2001). Negativity bias must be considered for this study as the natural tendencies of people to give greater weight to the negative might impact the frames (Ledgerwood & Boydstun, 2014). A neutral mindset prior to each frame would minimize this influence.

Method

Sample and Data Collection

Data was collected using an online survey from a sample of 80 early childhood education PSTs selected through convenience sampling. All participants were enrolled in an early childhood

education bachelor's degree program at an Australian University and gave informed consent. With university ethics clearance, the survey link was shared on the online student learning platform for the course. The disproportion of female to male early childhood teachers (Sumsion, 2005) was evident in the prominently female sample (95%) making gender comparisons unsound. Data on age, education level, early childhood experience and mathematics experience were all collected; however, only age produced meaningful findings. Participants were exposed to three tightly controlled treatments: the gain frame, loss frame, and non-frame in word problems. Precisely, a quasi-experimental approach was used as participants were not randomly assigned to select treatments but instead assigned to all of them (Cunningham, 2013). Real test stimuli inspired each of the treatments.

Stimuli

Word problems were adapted from the Year 9 NAPLAN numeracy test preparation materials offered by Education Queensland (Queensland Curriculum and Assessment Authority, 2017). NAPLAN is a national, annual assessment in Australia that tests whether school students are meeting relevant educational outcomes in literacy and numeracy. The test materials provided the two non-framed word problems for the survey and pilot study (see Table 1). The pilot test revealed that these stimuli balanced task difficulty, information salience and cognitive demand. The NAPLAN test materials categorize the word problems' difficulty levels which were adapted to the other word problems in the frames; two were developed for the gain frame and two for the loss frame.

The Framing Effect

The research design is informed and motivated foremost by the framing effect. The three frames were applied to the word problems with wording for the gain and loss frames influenced by Ledgerwood and Boydstun (2014). As noted earlier, there was consideration that the frames may stick and carry across word problems, particularly the negative frame. Therefore, prior to each set of framed word problems, the participants were induced with a neutral mood using the Velten Mood Induction Procedure, specifically the word-based induction tool (Kenealy, 1986). Additionally, steps were taken to ensure information salience was equal within the difficulty levels and frames.

Information Salience

With word problems, there is potential for distracting word noise (Endress et al., 2005). Applying the framing effect to word problems requires consideration of linguistics. Early research into word problems by Jerman and Rees (1972) found that many linguistic features, such as number of words and arithmetic operations, play a role in success despite mathematical equivalency or perceived difficulty. This is then coupled with information salience which brings in notions about obviousness of key information. To effectively complete the word problems, participants needed to filter out the relevant words then strategize. To make the three sets of word problems alike,

considered several features were considered, including word count, number of information sections, and mathematics operations (see Table 1).

Table 1

Stimuli Characteristics

Task	Word Count (Salience)	Information Sections	Mathematical Operations
Level 5 – Non-framed	26	2	3
	A pool filter processes 5400 litres of water in half an hour. Calculate how many litres of water the filter processes in 12 seconds.		
Level 7 – Non-framed	46	3	3
	A school has a total of 1500 students in Years 1 – 12. Three-fifths of the students are in the primary section in Years 1 to 7. 8% of the primary school students are left-handed. The number of left-handed students in the primary section is…		
Level 5 – Positive	26	2	3
	A popular lottery pays its lucky winner $18200 over 26 weeks. How much money is paid after 17 days, including that day? Use the daily average.		
Level 7 – Positive	46	3	3
	A miracle trial vaccine was given to 6000 patients spread evenly access 150 hospital in the world. Luckily, 60% of patients were fully cured and survived. 62 hospitals which trialled the new vaccine were private hospitals. How many of the cured patients were from private hospitals?		
Level 5 – Negative	26	2	3
	A government policy causes 3850 job losses of a 25-week period. Using the daily average, calculate how many people will become unemployed in 53 days.		
Level 7 – Negative	46	3	3
	A fatal and large-scaled earthquake strikes an international holiday resort that has 760 guests. One-fifth of the guests are visiting the resort for the first time. Sadly, 40% of the first-time guests are killed. What is the death total of first-time guests?		

Task Confidence

Without any prior knowledge of the word problems, it would have been impossible for the participants to determine true pre-task confidence. Consideration was given to how individuals perceive difficulty to assess confidence. Reinhard and Dickhäuser (2009) argued that there are four main cognitive factors in gauging difficulty: 1) need for cognition, 2) task difficulty, 3) cognitive strain, and 4) self-concept. Although the individual is responsible for the latter, difficulty cannot be gauged without a task presenting the first three factors (Reinhard & Dickhäuser, 2009). Reinhard and Dickhäuser (2009) inspired the development of this section of the survey to enable these three factors. Specifically: 1) task descriptions were given to the participants prior to viewing the wording which presents a challenge and engages need for cognition, 2) to determine task

difficulty, participants were told the origin of the problems and given difficulty levels, and 3) attempting the word problems caused a division in cognition between attention and memory causing cognitive strain. This provided grounding for the participants to gauge their pre-task confidence. Using scales, participants self-assessed pre-task and post-task confidence. The link between task confidence and the difficulty level of the word problems was observed in the main study and pilot study.

Pilot Study

In the developmental stages, an informal pilot study validated the choice of word problems. The problems needed to satisfy a Goldilocks-style requirement that they were not too difficult that they caused disengagement but not too easy that participants could solve them immediately to ensure sufficient exposure to the frames. The pilot study achieved this requirement by measuring four perceived elements: difficulty, confidence, anxiety level, and solvability. These elements are determiners of, and barriers to, task engagement in mathematics (OECD 2013). Existing word problems were used and taken from the 2010, Year 9 NAPLAN practice tests as it presented the appropriate degree of difficulty. Participants completed the measures before attempting the word problems to ensure that their responses were truly pre-task. Note that the pilot sample did not participate in the survey. The results of the pilot study were positive and showed that most participants were confident they could solve both word problems with strategies. There were mid-range averages of confidence, anxiety, and task difficulty meaning that the word problems were neither too hard nor too easy. The pilot study included an open-ended question where participants confirmed they were engaging with the information (see Tables 2 & 3). Confirming this engagement was important for ratifying exposure to the frames.

Table 2
Level 5 Word Problem Pilot Results

Participant	Difficulty[a]	Confidence[b]	Anxiety[c]	Solvable
1	6	5	8	Yes
2	6	6	7	Yes
3	4	2	2	Yes
4	1	1	2	Yes
5	2	3	5	Yes
6	5	7	5	Yes
7	1	1	2	Yes

8	7	7	6	Yes
9	2	1	1	Yes
10	1	1	2	Yes
11	3	3	4	Yes
12	4	4	4	Yes

[a]On a scale of 1 – 10 (1: easy for me – 10: impossible for me)
[b]On a scale of 1 – 10 (1: fully confident – 10: I wouldn't even bother)
[c]On a scale of 1 – 10 (1: no anxiety – 10: I am experiencing physical symptoms)

Table 3
Level 7 Word Problem Pilot Results

Participant	Difficulty[a]	Confidence[b]	Anxiety[c]	Solvable	Participant Comment
1	7	4	8	No	It looks so messy. I think I have a strategy for this one. I hate percentages. It would take me a long time, and I'd need a calculator and privacy.
2	8	8	8	Yes	I had to re-read it, but I understand; I have a strategy.
3	4	4	2	Yes	I definitely had to read it more than once.
4	2	1	2	Yes	Create a strategy. Just look at the numbers and do the maths.
5	2	2	3	Yes	The same as the previous one; re-read and create the strategy.
6	>5	8-9	>5	Yes	My first reaction was to completely disengage. I'd still attempt it, but I don't have much confidence I'd be correct. I need time.
7	3	2	2	Yes	It's messy at first, but it is easy to figure out.
8	9	9	6	Maybe	I don't get it. There are too many words.
9	4	2	1	Yes	It's the same as the first word problem, just a little bit harder though.
10	3	3	3	Yes	I read it a few times. With a pen and paper and a calculator it isn't too hard.
11	6	5	5	Maybe	This is harder because there is more information. If I can find the maths in it, I'm fine.

| 12 | 6 | 6 | 6 | No | I'm not good with reading all the words. Tell me the steps, and I can do it. |

[a]On a scale of 1 – 10 (1: easy for me – 10: impossible for me)
[b]On a scale of 1 – 10 (1: fully confident – 10: I wouldn't even bother)
[c]On a scale of 1 – 10 (1: no anxiety – 10: I am experiencing physical symptoms)

Results

The Framing Effect and Task Confidence

The data did not pass the assumptions for a Pearson's Product-Moment Correlation test. Hence, non-parametric testing was used. A Kendall's Tau-b correlation determined the relationship between pre-task and post-task confidence. Correlation strengths were interpreted using the rule of thumb given by Hinkle et al. (2003). Moderate-to-high, positive correlations that were statistically significant ($p < .001$) were found in all relationships with only slight differences in strength of correlation between the frames. The positive frame had the highest correlation ($n = 48$, $\tau_b = 0.72$), the non-frame was marginally less ($n = 45$, $\tau_b = 0.71$), and the negative frame was the weakest correlation ($n = 43$, $\tau_b = 0.63$). A Somers' Delta test confirmed the results. The negative frame was the only frame to have a medium effect size ($d = 0.34$) with pre-task confidence (Field, 2013). Each frame increased post-task confidence with the negative frame having the greatest impact increasing confidence by 12.9%, followed by the positive frame at 12.7% and the non-frame at 12.1%. This demonstrates no significant differences to PSTs' task confidence across frames.

Age

Age had no linear impact on task confidence when treated as a continuous variable. Pre-task confidence had a negligible correlation with age ($n = 60$, $\tau_b = -0.08$). When grouped categorically, the age group with the highest levels of task confidence was the 30 to 39 group ($n = 18$) and least confident was the 49+ group ($n = 4$). This was consistent in pre-task confidence and post-task confidence after all frames (see Table 4). However, these figures show that confidence peaked with the 30 to 39 age group and declined with the oldest age group having the lowest confidence.

Table 4
Mean Comparison of Age Groups' Confidence

Age Groups	Post-Task Confidence			Pre-Task Confidence
	Positive Frame	Non-Frame	Negative Frame	
<29	2.90	3.26	3.18	2.66
30-39	3.46	3.31	3.23	2.94
40-49	3.00	2.78	3.11	2.55
>49	2.75	2.00	2.25	1.75

Discussion

Task Confidence

The results of this study indicated that post-task confidence to be higher than pre-task confidence. It could be assumed that the sample overestimated the difficulty of Year 9 NAPLAN tests. The likely cause is self-bias; an underestimation of self-ability considering the moderate to low levels of self-belief amongst the sample and the poor mathematics attitudes identified in early childhood teachers and PSTs (Sweeting, 2011; Wilson, 2013). Cognitive bias is a common cause for people mistaking their own ability, and is often an underestimation (Ehringer et al., 2008). The participants underestimating their ability is consistent with the inverse of the Dunning-Kruger effect wherein people's assumption that they are unskilled is not reflected in their output (Kruger & Dunning, 1999). This bias is common in university students who tend to self-identify as unskilled which is reflected in their confidence (Ehringer et al., 2008). Therefore, it is apparent that cognitive biases caused low confidence prior to completing the word problems which allowed higher post-task confidence. This conclusion draws out questions about how biases bear across frames.

Frames and Confidence

The results do not suggest any impact on confidence as a result of how word problems are framed. Similarly, Lane and Reyes (2019) measured the relationship between word problems with gain and loss frames and university student performance and found negligible results. Of the three frames, the differences in confidence levels were marginal. As expected, the negative frame produced the highest confidence level, albeit indistinctly. Research by Ledgerwood and Boydstun (2014) determined that situations which involve loss linger and are most impactful. In their study, losses were immediately reframed to gains, yet the participants were unswayed by the reframing. In fact, regardless of the order of frames, the negative frame was residual. From this information, the finding from this study that negative frame generated a stronger boost in confidence is to be expected. However, this raises questions about how negative frames cause stronger increases. The linking factor here is task motivation which can be demonstrated by research using the Asian disease problem (Tversky & Kahneman, 1981).

The Asian disease problem is commonly used to research the framing effect's application to numbers (see Peng et al., 2013; Peters & Levin, 2008; Winskel et al., 2016). The Asian disease problem is a description of a fictional disease that threatens lives, and readers choose a resolution from four choices of lives lost or saved but are usually swayed by the wording to make illogical

choices (Tversky & Kahneman, 1981). Ledgerwood and Boydstun (2014) found the loss frame was more impactful as participants demonstrated higher levels of motivation and solving speed. An early study in sports research by Hanin (1978) found that athletes were able to improve confidence levels through framed self-motivatio which was validated 30 years later (Nicholls, 2010). Cognitive theories developed by Bandura (1986) suggest an inverse relationship where confidence is a crucial regulator of motivation. Surmising these findings demonstrates that the negative frame is a motivator that plays a direct role in confidence.

Age

Age did not have a linear impact on confidence but rather task confidence initially increased with age, peaked at 30-39 years then decreased with age. This pattern was consistent with pre-task confidence and post-task confidence across frames. All ages share low mathematics confidence and attitudes which deteriorate with age (Dowker et al., 2016). Dowker et al. (2016) suggested that the phenomenon is similar to young children drawing for pleasure regardless of artistic ability until they reach an age where they insist that they cannot draw. The results show that confidence levels were highest in the pre-middle aged participants suggesting that confidence in mathematics peaks at this age (see Table 4). Golomb (2002) suggested that cessation of drawing for pleasure during the transition into secondary school causes a peak in drawing confidence at that age then confidence declines. As it would be expected with any skill, confidence declines as the gap between current age and cessation age increases – the less time in practice, the less confidence lingers as suggested by the results in Table 4. Dowker et al. (2016) suggest that barriers to use are also responsible for low confidence in mathematics both in children and adults. In a similar way to the drawing analogy, they argue that desuetude is the culprit.

A common consensus in mathematics is that confidence levels decrease with age. With school children, research has shown how age is a key player in academic confidence (Cretchley, 2004). For instance, it is shown that older students perform better and confidently at mathematics than peers in the same grade (Thoren et al., 2016). This is consistent in children, but not in teenagers (Thoren et al., 2016). This shows that during schooling, our age does not have a linear impact on our confidence relative to peers. Dowker et al. (2016) contrasted this linear trend by arguing that mathematics confidence remains constant until developmental life stages where it suddenly slumps then gradually decreases. With university students, older students have varying mathematics confidence levels compared to traditional school-leaver peers (Cretchley, 2004). Consequently, a different pattern is identified where confidence decreases with age and older participants report dissimilar confidence levels. These findings raise concerns about the belief that age and mathematics confidence share a linear relationship. Research into mathematics confidence in adults is needed to uncover if the relationship with age is relative.

Conclusion

This study showed there was no significant differences between confidence levels of gain, loss and neutral frames. The results do not suggest any impact on early childhood PST confidence as a result of how word problems are framed. The main limitation of this study is the relatively low sample size. If this study were repeated, a greater number of students across a range of teaching specialties would be recruited. Furthermore, as early childhood PSTs are known for having poor relationships with mathematics, the results are not generalizable to a broader range of university students or teaching specializations.

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