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Art-Science Collaboration: The Role of Problematization and Artefact use

Collaboration between artists and scientists is often thought to benefit scientific creativity, the production of scientific knowledge that is both novel and of high quality. The added value of artists could be explained by the artist's skills in problematization, i.e. the skill of criticising theories to find new interesting outcomes; and the tendency to self-create artefacts to find common ground and ease communication to bridge the languages of different disciplines. In the present paper, a first experimental look is taken at the role of problematization and artefact use during art-science collaboration in early stages of the scientific process, in a student sample, where existing knowledge is investigated to develop a research question. The results of the study showed that self-created artefacts are a valuable asset in the communication between artists and scientists, even contributing to the novelty and overall quality of research questions through the process of problematization. As such, the contribution of this paper is preliminary experimental evidence of the added value of art-science collaboration for scientific knowledge production, and the role of problematization and self-created artefacts therein.

1 ART-SCIENCE COLLABORATION

"It has long been thought that a theorist is considered great because his theories are true, but this thought is false. A theorist is considered great, not because his theories are true, but because they are interesting" (p.1, Davis, 1971). Scientific creativity, the production of scientific knowledge that is both novel and of high quality, enables us to enjoy the latest technologies, live longer, and understand what it is that makes monumental works of art meaningful (Sawyer, 2011). However, multiple scholars have argued that scientific creativity should be supported more in both education and in research labs to facilitate and speed up the production of ground-breaking scientific knowledge (Sandberg & Alvesson, 2011; Bartunek, Rynes & Ireland, 2006; Davis, 1971; Weick, 1989). As one possible solution, it has been argued to facilitate interdisciplinary collaboration between scientists and artists as a way to support and even enhance scientific creativity.

Many organizations and academics have explored art-science collaboration as a way to either support artistic or scientific creativity (e.g., Richmond, 1984; Borgdorff, 2016; Stapper & Giaccardi; Horvath, 2007; Koskinen et al. 2011; Keyson & Bruns, 2009; Cole & Knowles, 2008). For example, artists now regularly work with material, computer, and life scientists to explore the potential of emerging media for artistic expression (Stocker & Hirsch, 2017). The work produced during such collaborations often contributes to public discussions about scientific advances and its implications for society, e.g. (Nunez, 2019). In turn, scientists have benefitted from art-science collaborations as well. For example, emotion psychologists have learned a great deal from collaborating with actors on how to conduct ecologically valid studies on emotion (Wagner et al., 2016), artistic work has informed the neuroscience of human perception (Zeki, 1999), and technological solutions developed by artists often show potential for real-world application, e.g. (de Rooij et al., 2018). Despite such advances, assumptions about the relationship between art-science collaboration and scientific creativity is too often based on anecdotal evidence, and on ground-breaking projects with mostly implications for the arts, e.g. (Stocker & Hirsch, 2017); but as of yet, less so for the sciences, cf. (de Rooij et al., 2018). This suggests that there is a need for research on how art-science collaboration can benefit scientific creativity.

Therefore, the present study investigates experimentally, in a student sample, the potential of art-science collaboration in the early stages of the scientific process: Where information is gathered, understood, and a research question is formulated. Specifically, it is proposed that artists are typically skilled in problematization, the skill of criticising theories to find new interesting outcomes, which could add to commonly used scientific approaches in a manner that enhances scientific creativity. Furthermore, it is explored whether the artist's tendency to self-create artefacts as a means of finding common ground and communication between the different languages of art and science facilitates the effective use of problematization on scientific creativity during art-science collaboration.

As such, the contribution of the present study is a first experimental look at the role of problematization and artefact use in art-science collaboration during the early stages of the scientific process.

2 THE ROLE OF PROBLEMATIZATION AND ARTEFACT USE

2.1 Creativity during early stages of the scientific process

Art-science collaboration may be particularly fruitful in the early stages of the scientific process, where information is gathered, understood, and research questions need to be formulated (Ruhl, de Rooij, & van Dartel, 2018). Basadur, Graen and Green (1982), however, showed that students find tasks that call for imagination and creativity difficult. An explanation provided by the authors is that schools generally reward systematic working more than creativity. Over the course of their study students showed to be less able to use their imagination than when they entered their educational program. A similar phenomenon is occurring in the academic world (Sandberg & Alvesson, 2011). There are strict methodological rules and social norms tied to studies which researchers are obliged to meet. Similar to schools, academia encourage this. Since researchers want to be sure to meet these standards, they have become more cautious in trying new things. This method for developing research is identified by Sandberg & Alvesson (2011) as: gap-spotting.

Gap-spotting

According to Sandberg & Alvesson (2011) the most commonly used method for formulating research questions is through gap-spotting. Gap-spotting is the development of new research based on what is presently missing in the literature. This can be done via confusion spotting (confusion in literature that needs clarification), neglect spotting (no research has been carried out on the topic) and combinations of the two. Generally, a research question can be considered 'good' if it is truthful and stems from rigorous research (Sandberg & Alvesson, 2011). Since gap-spotting is heavily grounded in existing literature, it is likely to yield truthful and good results. Although these criteria can determine whether a study is 'good', it does not mean the theory is interesting or creative (Bartunek et al., 2006, Davis, 1971, Weick, 1989). According to Davis (1971) what makes a theory interesting and creative is that it challenges the audience's assumptions of the theory. To establish this 'criticising' of a theory, Sandberg & Alvesson (2011) propose problematization as a method for the formulation of research questions; which can help support scientific creativity in these early stages of the scientific process.

Problematization

Sandberg & Alvesson (2011) argue that problematization involves knowing how to think out-of-the-box and different from what is already known. The central goal is "to disrupt the reproduction and continuation of an institutionalized line of reasoning" (2006, p. 32). In other words, it is seen as a means to not only identify but also challenge assumptions underlying existing theory.

From this, novel yet high quality research questions can be formulated. Problematization can occur via several routes. First, critical confrontation, which comprises the identification of shortcomings in a theory. Second, the development of a new idea, where the author claims innovation and does not follow a route mapped by literature. Third, problematization, which is a critical rethinking of a particular solution or theory. Other work and empirical observations are used as building blocks to stand on in the creation of innovative ideas. Following one of these routes for the development of research could support and enhance scientific creativity. According to Cropley, Kaufman and Cropley, problematization is part of novelty when assessing innovation.

Regardless of these newly established frameworks for developing research questions, according to Sandberg & Alvesson (2011) academics tend to prefer gap-spotting, because it is considered safe and uncontroversial. It increases the likelihood that the research will yield truthful and good results, and therefore to be published. This powerful tradition of developing new theory is hard to break. Yet, as argued in the above, it may also get in the way of the scientist's ability to produce knowledge that is novel. Leading to advances that are incremental rather than ground-breaking. One solution that may support and enhance scientific creativity may be to stimulate interdisciplinary collaboration between scientists and researchers from domains other than science where problematization is commonly preferred over gap-spotting.

2.2 Artistic competencies that may enable art-science collaboration

Art-science collaboration may depend on two crucial artistic competencies: 1) skilfulness in problematization, and 2) a tendency to self-create artefacts to aid (interdisciplinary) work.

Problematization as an artistic skill

Artists from various domains may represent such a group of researchers that are skilled in problematization. That is, it appears that the following competencies are generally attributed to artists active in the fine arts and the visual arts (Sullivan, 2010; Oakley, Sperry & Pratt, 2008) as well as artists active in the cultural industry, design and new media (Oakley, Sperry & Pratt, 2008). It is well established that artists are skilled in creating new and innovative concepts (Sullivan, 2010). However, it is not just this creativity that may make them valuable in interdisciplinary collaborations. Oakley, Sperry and Pratt (2008), for instance, stated that artists have a high disposition towards critical thinking. As a result of this disposition, artists often instigate critical discussions, which is useful for breaking down existing barriers and taboos within disciplines (Heinsius & Lehikoinen, 2013). Next to this, artists offer inspiration for topics to discuss, partly due to their preference for interpretive rather than analytical working methods (Hirsch et al., 2017). These assumed competencies are needed to be skilled in problematization (Sandberg & Alvesson, 2011). At least, more so than scientists. This skill can contribute to problematising theories, resulting in more novel research.

Artefact use as a facilitator

Artists may also bring a second skill to the table that is needed to unlock the potential of art-science collaboration within the context of scientific creativity, e.g. (van Dartel & de Rooij, 2019). Sullivan (2010) states that artists have the ability to, and systematically do, visualize problems and how they should be solved, also known as artistic cognition. Sullivan argues that an artist "uses many visual cognitive strategies that dislodge discipline boundaries" (p. 148). This is often aided by their skill in self-creating artefacts to find common ground and communicate ideas. Research through design methods suggests a similar function of self-created artefacts. According to Stappers et al. (2014), an artefact is a way to connect abstract theories and a carrier for (interdisciplinary) discussions. For example, artefacts can be used to demonstrate the possibilities of a new combination of elements, give direction to and unfold research by challenging it (Smith et al. 2016), be a vehicle for theory building (Koskinen et al. 2011, Stappers 2007, Wensveen & Matthews 2014), and help establish critical areas of concern and judgment (Gaver, 2012). Fundamentally, artefacts serve as a visualization of the current situation so this can be evaluated (Lim, Stolterman & Tenenberg, 2008) and during this evaluation new ideas and concepts can arise (Biggs & Karlsson, 2010). That is, visualizing ideas, both the scientist and artist could understand each other more clearly. It may therefore follow that to make use of the artist's skills in problematization, the self-creation of artefacts is needed to facilitate a clear overview of critical areas in a study based on which new ideas for research can be generated.

In the present study, it is therefore explored experimentally whether problematization enhances scientific creativity during art-science collaboration; and whether the self-creation of artefacts enables this effect of problematization.

3 METHOD

To explore the conjectures an experiment was conducted with a between-subjects design and with group type (i.e., type of collaboration) as the three-level manipulated factor.

3.1 Participants

Thirty students with a background in new media and communication science were recruited from Tilburg University ($M_{age} = 22$, $SD_{age} = 2.61$, 17 female, 13 male), and twenty-three students with a background in new media art (M_{age} = 23, SD_{age} = 2.52, 12 female, 11 male) were recruited from a media art program at AVANS University of Applied Sciences. In exchange for their participation, the students received course credit. The experiment was executed in the form of a workshop for which they were divided into three experimental groups: art-science (n = 8), art-art (n = 7) and science-science (n = 11) collaborations. Assignment to the groups was, aside from assignment based on background, done randomly.

3.3 Materials and measurements

Workshop about the potential of psychophysiology for new media

To test the role of artefact use and problematization in art-science collaboration a workshop was developed where participants were asked to develop a research question about psychophysiology, i.e., the correlations between physiological responses (e.g., heart rate) and psychological phenomena (e.g., emotions), within the context of new media research (e.g., using heart rate as a communication channel). At the start of the workshop the participants were familiarised with the topic of psychophysiology and its potential for new media via an introductory presentation by a workshop leader. The structure of the workshop was explained in this introduction as well. Participants were informed of the 45 minutes timeframe to develop a research question. They were advised to use the first 20 minutes to explore the phenomenon of psychophysiology. To this end, participants had access to the introductory presentation, a selection of relevant scientific research, and a psychophysiological sensor and visualization kit for hands-on exploration. A laptop with access to the internet was provided in case the participants wanted to search for more information or inspiration. After this initial exploration they were advised to brainstorm research ideas for 15 minutes; after which they were advised to spend the last 10 minutes of the workshop to converge upon and develop a research question. To enable the self-creation of artefacts, materials such as A3 paper and pencils were available during the workshop. Throughout the workshop, the participants were given ample opportunity to ask questions. During the forty-five minutes of collaboration the researcher remained in the room to observe the process and assist where needed.

Assessing problematization

Problematization was assessed in two ways. First, the disposition to problematize was self-reported before the workshop using the 5-point Likert scales (1 = not at all; 5 = extremely) taken from Runco, Plucker & Lim (2001), e.g. *I am able to think up answers to problems that haven't already been figured out.* The items were aggregated (mean) for each participant for use in the analysis. Second, problematization was measured as part of novelty, refer to section assessing scientific creativity. The items were based on Cropley, Kaufman & Cropley (2011) and measured whether the research question draws attention to shortcomings in other theories and how theories can be improved. This separate variable was created out of the three items measuring novelty to test whether self-create an artefact could contribute to problematizing theory, resulting in more novel research questions.

Assessing artefact use

Artefact use was self-reported using three 5-point Likert scales (1 = not at all; 5 = extremely): The use of an artefact made it easier for us to communicate; *The artefact contributed to the process of creating a research question; Without the artefact the collaboration would have been more difficult.* These were aggregated (mean) for each participant for use in the analysis.

Assessing scientific creativity

The quality of the research questions developed during the workshop was used as a proxy to assess scientific creativity during early stages of the scientific process. The novelty of the research questions was assessed with the novelty items, specifically: the use of existing knowledge, the initiation of new knowledge and problematization, from Cropley, Kaufman & Cropley (2011); whereas overall quality was assessed with the relevance, e.g. the *research question accurately reflects conventional knowledge,* effectiveness, e.g. *the research is easy to execute*, and elegance, e.g. *the research question is nicely formulated*, items. From these scales, safety and durability of the subscale relevance and external elegance, from the subscale elegance were excluded, as these could not be applied to the evaluation of research questions. Two independent expert raters used the scales to assess each of the research questions on 5-point Likert scale (1 = not at all to 5 = extremely). Scores on the items for novelty and for overall quality were aggregated (mean) for each participant to use in the analysis.

3.4 Procedure

Upon arrival participants were seated collectively in session of 6-10 people. First, they were introduced to the study, signed informed consent, and filled in a short questionnaire to capture their socio-demographics (incl. age, gender, background) and problematization disposition. Participants were then assigned based on their background, but otherwise randomly, to either a science-science, art-science, or art-art duo. The workshop with the science-science duos was organised at the research university, while the workshop with the art-art and art-science duos was organised at the art academy (the science students participating in the art-science duos travelled in). Hereafter, participants engaged in the workshop. After the workshop, the participants filled in a further questionnaire about the quality and novelty of the research questions and about their use of self-created artefacts. Finally, the researchers asked the participants to provide feedback on the workshop, the procedure and the cooperation between them and their partner. The research questions produced by the duos were rated by two experts as a proxy to assess scientific creativity during the early stages of the scientific process.

4 RESULTS

	Cronbach Alpha	Art-Art Mean (SD)	Science-Science Mean (SD)	Art-Science Mean (SD)
Problematization disposition	.727	3.53 (.59)	3.36 (.46)	3.25 (.57)
Problematization novelty	.700	3.38 (.58)	3.15 (.73)	3.52 (.58)
Artefact use	.961	3.89 (1.18)	2.65 (1.55)	4.06 (.52)
Research question novelty	.812	3.28 (.44)	2.87 (.48)	3.42 (.46)
Research question quality	.758	3.20 (.42)	2.94 (.51)	3.50 (.28)

Table. 1.
Cronbach's alpha and overall of mean (standard deviation) by group type.

4.1 The role of problematization

The role of problematization during art-science collaboration was explored by conducting several statistical tests. An independent t-test was conducted with artistic versus scientific background as the independent variable, and problematization disposition as the dependent variable. No significant difference was found, *Mdif* = .14, $t(51) = .94$, $p = .350$. However, a regression analysis showed that problematization disposition also did not significantly predict problematization novelty, $b = .16$, $\beta = .13$, $t(51) = .93$, $p = .359$. To further explore this a generalised linear model was calculated with group type as the independent variable, novelty as the dependent variable, and problematization disposition as a moderator. The omnibus test showed the test model to be better than the null-model, rejecting the null hypothesis, $\lambda = 15.98$, $df = 5$, $p = .007$. The test of model effects showed that the addition of problematization to the model was a significant improvement, $W_T = 9.06$, $df = 2$, $p = .029$, over the model without problematization disposition as the covariant, $W_T = 1.82$, $df = 3$, $p = .402$. However, the tests of fixed coefficients showed that the effect was only significant for the art-art group, $W_T = 8.22$, $p = .004$, 95% CI [.34, 1.79]. This relationship was positive, $B = 1.06$. Thus, this suggests that problematization disposition positively contributes to novelty, but only for art-art collaboration.

4.2 The role of artefact use

As conjectured, however, the added value of problematization that artists may add to art-science collaboration, may be dependent on the self-creation of artefacts to bridge the two disciplines.

To explore this an ANOVA was used with group type as the independent variable and artefact use as the dependent variable. The data for art-art (z-scores$_{kewness}$ = -2.57) and art-science (z-scores$_{kewness}$ = 3.34) were not normally distributed, therefore the p-values could be unreliable. Equal variances were not assumed, $F(2, 50) = 5.71$, $p = .006$, so the Welch statistic was reported. The results showed that there was a significant difference in the usefulness of self-created artefacts between the groups, $F(2, 28.14) = 7.73$, $p = .002$, $\eta^2 = .23$. Post-hoc comparisons (Tukey HSD) showed that artefact use contributed significantly more to the collaboration between artists and scientists than between scientists, $M_{diff} = 1.41$, $p = .003$, $d = 1.22$; and between artists than between scientists, Mdiff = 1.24, $p = .010$, $d = .90$; but not more between collaboration among artists versus collaboration between artists and scientists, $M_{diff} = .17$, $p = 1.00$. This suggests that people engaged in art-science and art-art collaborations find creating an artefact more helpful than people engaged in science-science collaborations.

Furthermore, a generalized linear model was used with group type as the independent variable, problematization novelty as the dependent variable, and artefact use as the moderator. The omnibus test showed that the test model was better than the null-model, rejecting the null hypothesis, = 12.90, $df = 2$, $p = .002$. The test of model effects showed that the addition of artefact use to the model was a significant improvement, $W_T = 15.13$, $df = 3$, $p = .002$, over the model without artefact use, $W_T = 13.00$, $df = 2$, $p = .002$. The parameter tests showed that the effect was significant only for the art-science group, $W_T = 9.92$, $p = .002$, 95% CI [.90, 3.88]. This relationship was positive, $B = 2.39$. Tests adding problematization disposition as moderator (nor in addition to problematization novelty) did not yield further results that contribute to the reported findings. As such, these results suggests that the self-creation of artefacts facilitates problematization specifically during art-science collaboration.

To explore whether the positive effects of art-science collaboration on scientific creativity depended on the found relationship between artefact use, a generalized linear model was calculated with group type as the independent variable, independently research question quality as the dependent variable, and artefact use as the moderator. The omnibus test showed that the model was better than the null-model, $\lambda = 24.23$, $df = 5$, $p < .001$. The test of model effects showed that the edition of artefact to the model was a significant improvement, $W_T = 13.16$, $df = 3$, $p = .004$, over the model without artefact, , $W_T = 6.90$, $df = 2$, $p = .032$. The parameter tests showed that the effect was significant only for the art-science group, $W_T = 10.25$, $p = .001$, 95% CI [1.00, 4.17]. This relationship was positive, $B = 2.59$. This finding therefore suggests that the creation of an artefact also positively contributes to the overall quality of research questions in art-science collaborations.

4.3 Relationship with scientific creativity

To explore whether art-science collaboration supports or even enhances scientific creativity and ANOVA was calculated with group type as the independent variable, and independently research question novelty and research question quality as the dependent variables.

For novelty, the data was normally distributed and the assumption of homogeneity was met. The results showed there was a significant difference in novelty between groups, $F(2, 50) = 7.30$, $p = .002$, $\eta^2 = .23$. Post hoc comparisons (Tukey HSD) showed novelty was significantly higher for a collaboration between artists and scientists than between scientists, $M_{diff} = .55$, $p = .002$, $d = 1.17$, and between artists than between scientists, $M_{diff} = .41$, $p = .030$, $d = .87$. This finding suggest that art-science collaborations lead to significantly more novel research questions than science-science, but not art-art.

For overall quality, the data for art-art ($\text{z-scores}_{\text{kewness}} = -2.20$) was not normally distributed, therefore the p-values could be unreliable. The assumption of homogeneity was met. The results showed there was a significant difference in overall quality between groups, $F(2, 50) = 7.78$, $p = .001$, $\eta^2 = .24$. Post hoc comparisons (Tukey HSD) showed overall quality was significantly higher for a collaboration between artists and scientists than between scientists, $M_{diff} = .55$, $p = .001$, $d = 1.35$. This finding suggest that art-science collaborations lead to significantly higher overall quality of research questions than science-science.

Further testing revealed no clear relationships within the art-science collaborations for artefact use and novelty. Additionally, the relation between problematization disposition and overall quality was tested, which proved not to be significant. Lastly, the combined effect of problematization disposition and artefact use was tested on novelty and overall quality but showed no clear relationship.

5 CONCLUSION AND DISCUSSION

The presented study explored experimentally, in a student population, the potential of art-science collaboration to support scientific creativity during early stages of the scientific process, and in particular the role of problematization and self-created artefact use therein. The results showed no evidence indicative of a difference between artists and scientists in the sample regarding a disposition to engage in problematization. However, when examining the influence of problematization on the novelty of research questions, problematization did affect this relationship, but only in the collaboration between artists. Rather, the role of problematization in novelty of the research questions depended on the use of self-created artefacts; and the use of self-created artefacts contributed to the overall quality of the research questions developed specifically during the art-science collaborations. This suggests that during art-science collaborations self-creation of artefacts facilitates the problematization of novelty of the research questions, which supports the quality of the research questions that are developed.

Of course, there are also limitations to the presented study that have implications for the validity of the presented results. First, the use of a student sample may not be sufficiently ecologically valid. Case in point is the suggestion that artists have a high disposition toward critical thinking and a high tolerance for uncertainty, which is assumed to underlie a disposition to engage in problematization (Oakley, Sperry and Pratt, 2008); and the suggestion of Sandberg and Alvesson (2011) that scientists are hesitant to try new theories. In the present study, however, artists did not have a higher disposition to engage in problematization than scientists. This could be explained by the use of a student sample. For instance, differences in problematization disposition may emerge later in the artist's and scientist's development. Caution is therefore advised when interpreting this particular result. Second, the null finding between artists and scientists regarding problematization disposition is also interesting in light of conducting experimental studies on art-science collaboration. That is, this null finding could also be explained by the idea that generalization of artists and scientists competencies is misconceived. Indeed, people (and thus artists and scientists) are always subject to individual differences (Goldberg, 1990), which may affect (interdisciplinary) collaboration and scientific creativity in a variety of ways. It is therefore tedious to base experimental studies on competencies attributed to either artists or scientists. Future research needs to take into account that assumptions about artist's and scientist's competencies, despite evidence from previous work, may vary. Using a preselected sample based on assumed competencies is advised. Third, not all relationships between problematization and the production of novel and quality research questions could reliably be tested, e.g. the interaction of problematization and artefact use and their combined moderating effect. This is partly due to the exploratory nature of the study and the relatively low sample size. This in turn invites an increased chance on Type I and Type II errors. We therefore wish to emphasise that the results of this study need to be seen as preliminary, and that confirmation on the basis of this exploratory study is required to achieve more certainty about the role of problematization and artefact use during art-science collaboration; within the context of supporting and enhancing scientific creativity during early stages of the scientific process.

As such, the contribution of this study is that it offers preliminary evidence that suggests that the self-creation of artefacts enables a beneficial effect of art-science collaboration on scientific creativity, possibly via the engagement of artists and scientists in problematization during such collaborations.

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