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# INTEGRATING SOCIO-SCIENTIFIC ISSUES INTO VOCATIONAL DESIGN EDUCATION: EFFECTS ON STUDENTS' ETHICS AWARENESS, SOCIAL RESPONSIBILITY, AND DESIGN OUTCOMES

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**Abstract.** *This study explores the effects of embedding Socio-Scientific Issues (SSI) into vocational design education on students' ethics awareness, social responsibility, and design performance. A mixed-methods quasi-experimental design was employed, involving 80 vocational design students divided into an experimental group (SSI-based workshop) and a control group (traditional workshop). Ethics awareness and social responsibility were assessed using the Attitudes toward the Ethics of Artificial Intelligence (AT-EAI) and the Chinese College Student Personal Responsibility Scale (CCSPRS), respectively. Performance was evaluated using a rubric-based assessment. Qualitative data were obtained from students' reflective reports. ANCOVA results revealed that the experimental group significantly outperformed the control group in post-test scores of ethics awareness and social responsibility ($p < .05$). Additionally, they scored significantly higher in ethical sensitivity and user experience, though not in scientific accuracy creativity, or visual expression ($p < .05$). Thematic analysis indicated that students in the SSI group demonstrated deeper ethical reasoning, increased empathy, and a redefined sense of the designer's social role. SSI-based teaching not only enhances students' ethical and civic competencies but also influences how they embed values into design. It highlights the transformative potential of SSI pedagogy in vocational design education.*

**Keywords:** *socio-scientific issues, design education, vocational students, ethics awareness, social responsibility*

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## Introduction

With the rapid advancement of technology, particularly driven by artificial intelligence (AI) and data technologies, the field of modern design is facing unprecedented opportunities and challenges. Design is no longer merely a tool to meet user needs; it has evolved into a crucial force for assuming social responsibility and driving societal transformation. As AI, automation, and big data analytics become increasingly integrated into everyday life, designers are expected not only to possess innovative design thinking but also to demonstrate a keen awareness of the ethical and social implications of technology applications.

### *SSI and Constructivist Learning Theory*

Socio-Scientific Issues (SSI) refer to complex problems at the intersection of science, ethics, and society that involve value-laden decision-making and typically lack a single correct solution. These issues require the integration of perspectives from multiple disciplines for in-depth analysis and discussion (Ban & Mahmud, 2023). SSI instruction was first introduced by (Sadler, 2004) to promote students' critical thinking, ethical reasoning, and scientific argumentation by bringing controversial science-related societal issues into the classroom. (Sadler, 2011) further emphasized that SSI instruction goes beyond the transmission of scientific facts, aiming instead to develop students' ability to weigh moral, ethical, and social considerations when engaging with science and technology.

In the context of design education, integrating SSI into the curriculum carries particular significance, especially against the backdrop of rapidly advancing technologies. Ethical dilemmas related to emerging technologies such as artificial intelligence and gene editing are gaining public attention. Addressing these issues in the classroom helps students not only understand the underlying scientific principles but also reflect on the long-term societal implications of design decisions from ethical, sociological, and cultural



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perspectives (Chung et al., 2016; Gazulla et al., 2025). An increasing body of research shows that SSI instruction effectively fosters students' scientific literacy, ethics awareness, and sense of social responsibility (Namdar & Namdar, 2021; Ottander & Simon, 2021; Zeidler & Keefer, 2003).

Meanwhile, constructivist learning theory offers a strong theoretical foundation for SSI instruction. At its core, constructivism posits that learning is an active process of knowledge construction, in which learners develop understanding through interaction with their environment and others (Narayan et al., 2013). From this perspective, learning should not be limited to the acquisition of facts and information, but rather should involve solving real-world problems to promote deeper understanding and critical reflection. In SSI-based instruction, students participate in discussions on ethical and societal implications, enabling them to build comprehensive understandings of complex issues through situated learning (Mathers et al., 2024). This approach emphasizes learning by doing (Lesgold, 2001) and reflective practice (Daff et al., 2024), which supports students in developing the ability to balance technological, ethical, and societal factors in design decision-making.

The combination of SSI instruction with constructivist learning theory creates a rich, multidimensional learning environment in which students are not merely "learners" but become active participants in societal issues and responsible agents in design decision-making (Pande & Bharathi, 2020). Through this approach, education transcends the transmission of knowledge, empowering students to learn how to address complex ethical and social challenges embedded in real-world contexts.

### *Ethics Awareness*

Research on ethics awareness in education has undergone several developmental stages, with its importance becoming increasingly prominent in the context of science and technology education. Ethics awareness refers to an individual's sensitivity and understanding of moral issues, particularly the ability to make socially responsible judgments when faced with ethical dilemmas (Lofstrom, 2012). In educational contexts, the cultivation of ethics awareness involves exposing students to real-world ethical controversies to help them develop moral reasoning in complex social settings and take responsibility for the consequences of their actions (Lau, 2010; Zeidler et al., 2005).

In design education, fostering ethics awareness is especially critical. As technology advances, the influence of design has extended beyond product functionality and user experience to encompass broader societal, environmental, and cultural dimensions. Designers act as intermediaries between technology and society; thus, their decisions directly or indirectly shape various aspects of the social world. Designers with strong ethics awareness are better equipped to identify and navigate ethical challenges in the design process and avoid producing socially harmful outcomes (d'Anjou, 2011; Gasparski, 2003; Zhong et al., 2023). For instance, in domains such as AI and automation, designers must confront ethical concerns like data privacy, algorithmic bias, and misuse of technology. Therefore, cultivating ethics awareness is essential for developing both professional and social responsibility in future designers (Pant et al., 2024; Siau & Wang, 2020).

### *Social Responsibility*

Social responsibility refers to an individual's sense of obligation and accountability within a societal context, particularly in relation to others, the environment, and the public good. It reflects a willingness to act and contribute positively when these dimensions are at stake (Alimin et al., 2024). As a critical objective of education, fostering social responsibility aims to help students understand the potential impacts of their actions on society, the environment, and future generations, and to motivate responsible attitudes and behaviors (Bielefeldt & Canney, 2016; Vutsova et al., 2023).

In the context of design education, social responsibility plays a vital role. The work of designers goes beyond meeting market and user demands; it also involves considering the broader societal and environmental implications of their creations (Mao, Han, et al., 2024; Papanek, 1985; Yang, 2015). With the accelerating pace of globalization and information technologies, designers must take into account a wider range of responsibilities, including environmental sustainability, resource conservation, cultural preservation, and issues of ethics and equity (Adamek, 2018). Therefore, design education should not only develop students' creativity and technical skills but also strengthen their sense of social responsibility. Students must come to see that design is not merely about serving individual clients or user groups, but about contributing to the collective well-being of society as a whole.


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*Research Problem*

Although SSI instruction has achieved notable outcomes in the contexts of science and ethics education, empirical research on its application in design education remains scarce (Ban & Mahmud, 2023). Most existing design curricula still focus primarily on technology, function, and aesthetics, often neglecting the ethical dilemmas and social impacts underlying design practices (Mao, Ban, et al., 2024). This gap becomes particularly salient in high-tech domains such as AI, where designers frequently lack sufficient ethical judgment and a strong sense of social responsibility (Brusseau, 2023; Jiang et al., 2023). Therefore, this study seeks to explore whether the integration of SSI instruction into vocational design education can effectively enhance students' ethics awareness and social responsibility, while also improving the quality of their design outcomes. By addressing these questions, the study aims to provide empirical evidence to support innovation in vocational design education and to cultivate socially responsible designers capable of meeting the ethical challenges of future technologies.

*Research Aim and Research Questions*

The aim of this study was to explore the effects of integrating SSI into design education on vocational design students' ethics awareness, social responsibility, and design performance. By embedding the SSI topic "AI Companions and the Reconstruction of Human Relationships" into a design workshop, the study sought to assess whether this educational approach can enhance students' critical thinking and sense of responsibility when dealing with complex technological and ethical issues, and to evaluate its effects on the quality of their design outcomes.

Specifically, this study aimed to address the following research questions:

RQ1: Can SSI-based education improve ethics awareness among vocational design students?
RQ2: Can SSI-based education enhance vocational design students' sense of social responsibility?
RQ3: Can SSI-based education improve the quality of design outcomes among vocational design students?
RQ4: What are the learning and thinking processes experienced by vocational design students during SSI-based education?

## Research Methodology

*General Background*

This study employed a mixed methods research approach, specifically adopting an explanatory sequential design framework (McCrudden & McTigue, 2019). The research was initiated on September 1, 2024, and data collection took place from November 5 to November 7, 2024. The study focused on students at the vocational college level and was conducted within the scope of design education programs in eastern China. The research began with a quantitative quasi-experimental phase to examine the effects of educational intervention, followed by qualitative analysis of reflective reports to provide deeper insights into students' learning processes and value transformation. The quantitative component aimed to measure changes in students' ethics awareness, sense of social responsibility, and design performance before and after the intervention. The qualitative component explored the mechanisms of students' thinking and learning during the design process. By triangulating multiple sources of data, this study sought to comprehensively uncover the ways in which SSI-based instruction influences design students' competence development and its broader educational implications.

*Participants*

A priori power analysis was conducted using G*Power 3.1.9.7 to determine the minimum required sample size for this study. For the ANCOVA analysis, with one covariate and two groups, parameters were set to $f = 0.40$, $\alpha = .05$, and power = 0.80. The results indicated that a minimum of 52 participants would be needed. The independent samples t-test analysis ($r = 0.40$, $\alpha = .05$, and power = 0.80) showed that at least 34 participants were required. The participants in this study were 80 second-year vocational college students majoring in Product Design and Visual Communication Design at a higher vocational institution in eastern China. The students were between 18 and 23 years old. To ensure fairness in comparison and control over the educational conditions, a quasi-experimental design was adopted. Each student was assigned a number, and these numbers were randomly shuffled and assigned to


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either the experimental group (EG) or the control group (CG) using Excel's random number generator function. Each group consists of 40 students, which is close to the size of their normal classes. All participants were second-year students from the same vocational college, majoring in the same program. This ensured that they had similar prior learning experiences in design. Additionally, none of the participants had received any systematic education related to AI ethics or socio-scientific issues before the study.

Prior to the intervention, all participants signed informed consent forms, acknowledging their understanding of the study's purpose, the content of instructional activities, participation procedures, and the intended use of data. Participation in the study was entirely voluntary, and all personal information was anonymized during data analysis. To further minimize confounding variables, both groups received equal treatment in terms of total instructional time, instructor guidance, project structure, and expected deliverables. The only difference between the two groups lay in the inclusion of SSI-based content in the experimental group's instruction.

### *Procedures*

To evaluate the effects of SSI-based instruction in design education, two parallel educational interventions were developed—one for the experimental group and one for the control group. Both interventions followed an identical structure and revolved around the central theme of "AI Companions," delivered through a three-day intensive design workshop. The two groups received instruction with equivalent learning objectives, session durations, teacher facilitation, and output formats. The key difference lay in the inclusion of the SSI topic "AI Companions and the Reconstruction of Human Relationships" in the experimental group, which introduced ethical dilemmas and socio-scientific contexts for discussion and design. The overall workshop procedure is presented in Table 1, with differences between the experimental and control groups highlighted in bold.

**Table 1**
*Workshop Procedure*

| Phase | Duration | Learning objective | Activity description | Expected output |
|---|---|---|---|---|
| 1. Introduction to the Topic & Cognitive Activation | 60 minutes | Understand the basic functions and interaction logic of AI companions | Watch a real documentary clip or news case;<br>**Pose the question "Would you be willing to live with an AI companion?" (EG);**<br>Group discussion (5 students in one group). | Student-generated questions and opinions (post-it notes) |
| 2. User Role Building & Needs Analysis | 60 minutes | Cultivate empathy and understand human–AI interaction needs | **Group discussion: "AI companions and the restructuring of human relationships" (EG);**<br>Explore emotional/ ethical/ safety needs of different users;<br>Create user personas and storyboard. | User personas and storyboards |
| 3. Ethical Conflict Scenario Construction | 120 minutes | Enhance sensitivity to ethical issues and critical thinking | Instructor introduces several AI ethics case studies (e.g., AI in relationships, AI impersonating humans);<br>**Debate topic: "Can AI be a friend of humans?" (EG);**<br>**Role-play debate and propose ethical design principles (EG);**<br>**Open group discussion and ethical design principles (CG).** | Group discussion sheet and Ethical Design Principles Cards |
| 4. Design Prototype Development | 240 minutes | Integrate socio-scientific issues into product design | **Introduce "ethical constraint" mechanism (EG);**<br>Each group creates an interface/product prototype based on a specific AI companion usage scenario;<br>Options include hand drawing, paper prototyping, or Figma sketching. | Hi-fi prototype sketches and design rationale |
| 5. Presentation & Feedback | 120 minutes | Promote social responsibility reflection and develop presentation/defense skills | Group presentation of design concepts;<br>Respond to ethical critiques and improvement suggestions from peers. | Presentation slides and reflection records |

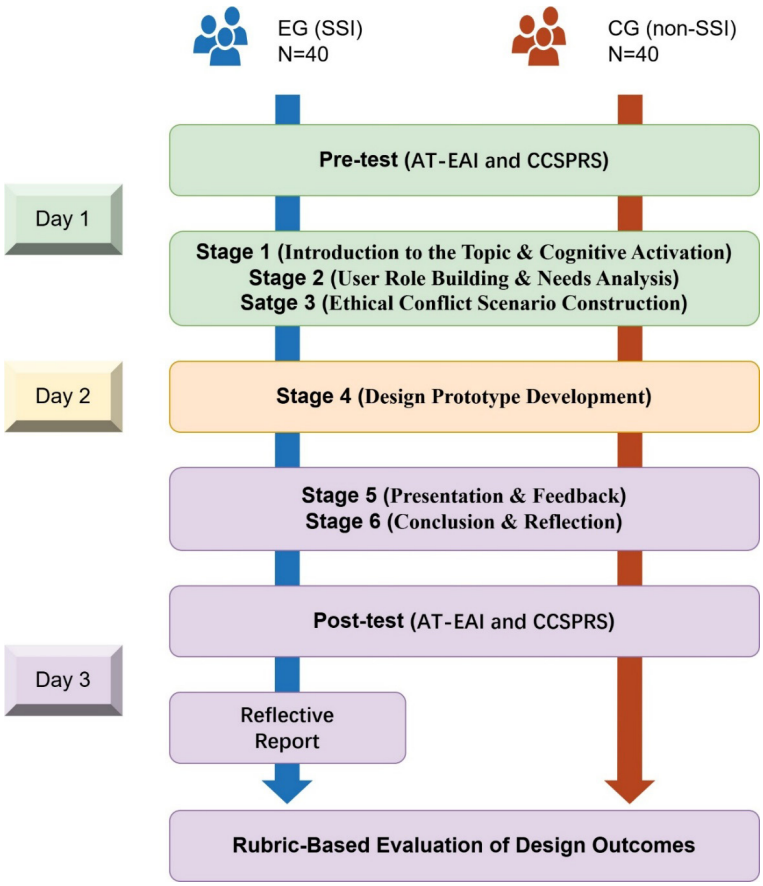

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| Phase | Duration | Learning objective | Activity description | Expected output |
|---|---|---|---|---|
| 6. Conclusion & Reflection | 60 minutes | Consolidate learning outcomes and evaluate growth in design literacy | Summarize learning process and outcomes; Q&A session. | Personal reflection summary |
| 1. Introduction to the Topic & Cognitive Activation | 60 minutes | Understand the basic functions and interaction logic of AI companions | Watch a real documentary clip or news case; **Pose the question "Would you be willing to live with an AI companion?" (EG);** Group discussion (5 students in a group). | Student-generated questions and opinions (post-it notes) |

The experimental procedure is illustrated in Figure 1. On the first day, both groups of students completed a pre-test. This was followed by a three-day design workshop, during which the experimental group received SSI-based instruction, while the control group followed a standard curriculum without SSI integration. After the workshop concluded, all students completed a post-test, and students in the experimental group submitted a Reflective Report. Finally, their design outcomes were evaluated by four instructors using a standardized rubric.

**Figure 1**
*Experimental Procedure*




*Instruments*

Ethics awareness was assessed using the Attitudes toward the Ethics of Artificial Intelligence (AT-EAI) (Jang et al., 2022). This instrument evaluates students' attitudes toward AI ethics and has been validated for strong reliability and construct validity. It includes five dimensions: fairness, transparency, non-maleficence, privacy, and responsibility. The scale consists of 17 items rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).


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Social responsibility was measured using the Chinese College Student Personal Responsibility Scale (CCSPRS) (Ren et al., 2023), developed to assess personal and social responsibility among Chinese university students. The scale has demonstrated sound reliability and validity and contains three dimensions: responsibility cognition, sense of responsibility, and responsibility behavioral tendency. It consists of 13 items, including 4 reverse-scored items. Responses were collected using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). In a pilot study involving 30 students, the Cronbach's α coefficients for the two Chinese-language instruments were .88 and .85, respectively.

The quality of students' design outcomes was evaluated by four design instructors with extensive teaching experience, using a rubric developed by the research team (Dawson, 2017). The rubric included five criteria: scientific accuracy, ethical sensitivity, user experience, creativity, and visual expression. Each criterion was rated on a 5-point scale. After expert review and revisions, the rubric was implemented in the pilot phase. Inter-rater reliability was confirmed through Pearson correlation ($r = .82$, $p < .001$) and Cohen's $\kappa$ ($\kappa = .79$), indicating high consistency and scoring reliability.

Qualitative data were collected through Reflective Reports, consisting of four open-ended questions (Table 2). Students were asked to write brief reflections (100–150 words each) for each question and were encouraged to provide examples where relevant.

**Table 2**
*Reflective Reports*

| NO. | Question |
|---|---|
| 1 | Did you apply any scientific knowledge in your AI companion design task? If so, what specific knowledge did you use, and how did it help you improve your design? |
| 2 | Did you consider any ethical issues that might arise in your design? What were those issues, and how did you attempt to address them? |
| 3 | Do you think your design could have a positive impact on society? Why or why not? If not, what aspects would you like to improve? |
| 4 | What was your biggest takeaway from this design activity? How has it inspired your future development as a designer? |

### *Data Analysis*

For the two variables with pre-test data, Analysis of Covariance (ANCOVA) was employed. Pre-test scores were used as covariates to control initial differences between groups. The independent variable was group (experimental vs. control), and the dependent variable was the post-test score. This method allowed the researchers to assess the true effect of instructional intervention on students' core competencies while accounting for baseline disparities (Mishra et al., 2019). Data were analyzed using SPSS 26.0. Significance level ($p < .05$), effect size ($\eta^2$), and descriptive statistics (means and standard deviations) were reported. To ensure the validity of ANCOVA assumptions, the study tested for linearity between the covariate and dependent variable, homogeneity of variance, and homogeneity of regression slopes.

For evaluating the quality of design outcomes, which did not involve pre-test data, independent samples t-tests were conducted to determine whether there were significant differences between the experimental and control groups in the five rubric dimensions and total scores of the final design projects.

Qualitative data were analyzed using thematic analysis (Braun & Clarke, 2006) based on Reflective Reports submitted by students in the experimental group. The analysis followed six stages: familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. The research team coded all report texts to identify students' key cognitive and emotional expressions related to scientific thinking, ethical reasoning, and social responsibility.

## Research Results

### *Ethics Awareness*

Prior to conducting the ANCOVA, the underlying assumptions of the analysis were tested. The homogeneity of regression slopes assumption was confirmed, as the interaction term between educational group and pre-test ethics awareness was not significant, $F(1, 76) = 2.516$, $p = .117$. Levene's test for equality of variances also yielded a


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non-significant result, $F$ (1, 78) = 0.187, $p$ = .667. In addition, scatterplots indicated a reasonably linear relationship between pre-test and post-test scores on ethics awareness.

Table 3 presents the results of the ANCOVA for ethics awareness. After controlling for pre-test scores, students who received SSI-based instruction scored significantly higher on ethics awareness in the post-test compared to those who received traditional instruction. The partial eta squared ($\eta^2$) value was .108, indicating a medium effect size of the instructional approach on students' ethics awareness.

**Table 3**
*ANCOVA Results for Ethics Awareness Between the Experimental Group and Control Group*

| Group | N | M | SD | Adj. M | F | p | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| EG | 40 | 4.46 | 0.24 | 4.38 | 9.179 | .003 | .108 |
| CG | 40 | 3.54 | 0.24 | 3.64 | | | |

*Social Responsibility*

The assumption of homogeneity of regression slopes was tested and confirmed, as the interaction between instructional group and pre-test scores on social responsibility was not significant, $F$ (1, 76) = 0.132, $p$ = .717. Levene's test for equality of variances also yielded a non-significant result, $F$ (1, 78) = 0.086, $p$ = .770. Furthermore, the scatterplot of pre-test and post-test scores indicated a clear linear trend.

Table 4 presents the ANCOVA results for social responsibility. After controlling for pre-test scores, students in the SSI-based instructional group scored significantly higher on social responsibility in the post-test than those in the traditional instruction group. The partial eta squared ($\eta^2$) was .107, indicating a medium effect size of the instructional method on students' sense of social responsibility.

**Table 4**
*ANCOVA Results for Social Responsibility Between the Experimental Group and Control Group*

| Group | N | M | SD | Adj. M | F | p | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| EG | 40 | 4.29 | 0.26 | 4.21 | 9.078 | .004 | .107 |
| CG | 40 | 3.36 | 0.25 | 3.44 | | | |

*Quality of Design Outcomes*

Table 5 presents the results of the independent samples $t$-tests on the quality of students' design outcomes. No significant differences were found between the experimental and control groups in terms of scientific accuracy, creativity, or visual expression ($p$ > .05). However, students in the experimental group scored significantly higher in ethical sensitivity, user experience, and overall performance compared to those in the control group ($p$ < .05).

**Table 5**
*Independent Samples t-Test Results for the Quality of Design Outcomes*

| Variable | Group | N | M | SD | t | p |
|---|---|---|---|---|---|---|
| Scientific accuracy | EG | 40 | 3.32 | 0.52 | .718 | .475 |
| | CG | 40 | 3.23 | 0.57 | | |
| Ethical sensitivity | EG | 40 | 4.11 | 0.37 | 10.217 | < .001 |
| | CG | 40 | 3.15 | 0.47 | | |
| User experience | EG | 40 | 3.89 | 0.42 | 8.864 | < .001 |
| | CG | 40 | 3.05 | 0.44 | | |


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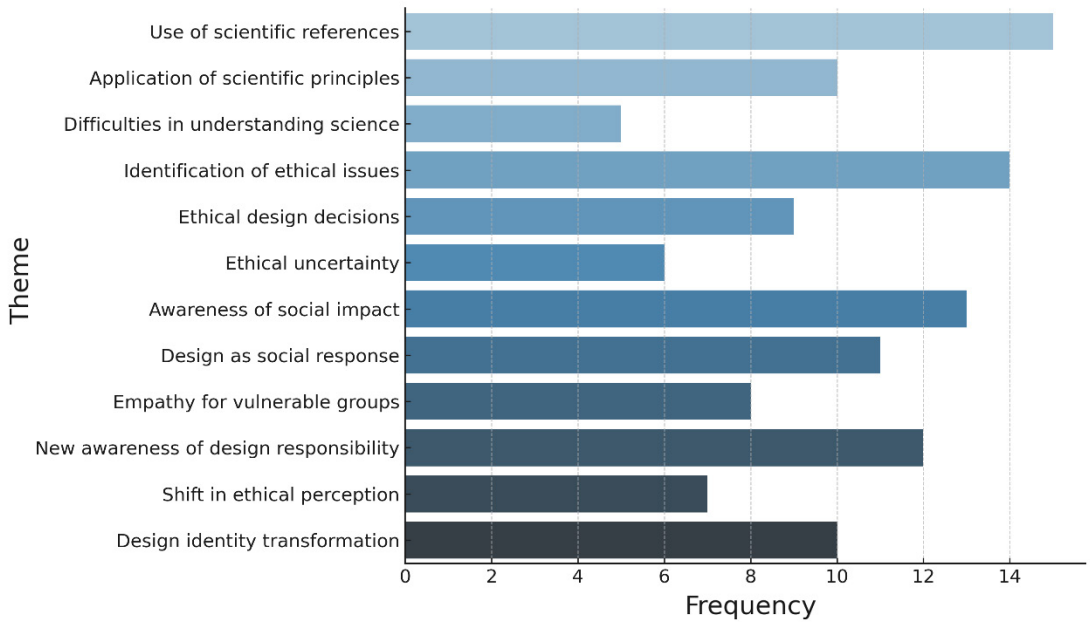
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| Variable | Group | N | M | SD | t | p |
|---|---|---|---|---|---|---|
| Creativity | EG | 40 | 3.55 | 0.50 | -.761 | .449 |
| | CG | 40 | 3.64 | 0.53 | | |
| Visual expression | EG | 40 | 3.38 | 0.56 | .542 | .589 |
| | CG | 40 | 3.31 | 0.46 | | |
| Total | EG | 40 | 18.25 | 1.00 | 7.737 | < .001 |
| | CG | 40 | 16.38 | 1.16 | | |

*Learning and Thinking Processes*

A thematic analysis of 40 Reflective Reports written by students in the experimental group revealed that the SSI-based instructional intervention significantly influenced students' thinking patterns and design awareness across multiple dimensions. The frequency distribution of the identified themes is presented in Figure 2.

**Figure 2**
*Theme Frequency from Reflective Reports*




First, in terms of the application of scientific knowledge in design, the vast majority of students mentioned in their reflections that they proactively consulted information related to artificial intelligence during the project and attempted to apply scientific principles in their design.

> *"I looked up the basic principles of AI language models and incorporated an emotional recognition module in the interface design."* (S01)
> *"I referred to real user behavior data to infer how the AI companion would behave in different usage scenarios."* (S05)

These statements suggest that SSI instruction encouraged students to translate scientific knowledge into practical design strategies. However, some students also noted their limited understanding of scientific content, as expressed by S14:

> "Although I don't fully understand AI, I tried to grasp how it interacts with users by learning from data."


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This highlights the differences in students' levels of scientific literacy.

On the dimension of ethics awareness, the Reflective Reports revealed that students generally recognized the moral risks associated with the use of AI products in real life, particularly in relation to emotional dependency and privacy concerns.

> *"What worries me most is that users may become emotionally dependent on the AI, so I added an 'emotional reminder mechanism' to help users realize it's not a real person."* (S12)
> *"I considered that AI might collect a lot of private information, so I added a data anonymization feature."* (S20)

These measures indicate that students had begun to establish ethical boundaries during the design process. Nevertheless, some students showed vague ethical judgments. As S27 noted:

> "I feel like there's something 'not quite right' about the design, but I can't pinpoint the exact issue."

This suggests that while students' ethical awareness is awakening, their moral reasoning abilities still need further development.

In the dimension of social responsibility, many students demonstrated a concern that went beyond user-centered thinking and tried to frame their design as a response to broader societal issues.

> *"I hope the AI companion is not only a source of emotional comfort, but also serves a social function by accompanying lonely elderly people."* (S08)
> *"I envisioned the user as someone with hearing impairments, so I added a visual feedback system."* (S16)

These responses indicate that SSI instruction effectively guided students to pay attention to marginalized groups in society and inspired them to take on broader social responsibilities in their designs.

Finally, in the dimension of designer identity and professional awareness, students generally expressed a shift in their perception of the designer's role, viewing design not merely as a technical task but as a value-driven social act.

> *"This course made me realize that being a designer is not just about aesthetics and functionality, but also about being socially responsible."* (S04)
> *"I never used to think about ethics, but now I know that even the design of a button can influence users' decisions."* (S10)

These reflections suggest that students have begun to see themselves as socially responsible and ethically conscious designers, rather than passive executors.

## Discussion

This study found that students who received SSI-based instruction performed significantly better than those in the control group in terms of ethics awareness and social responsibility. Their design outcomes also demonstrated stronger ethical sensitivity, improved user experience, and higher overall quality. Although no significant differences were found in scientific accuracy, creativity, or visual expression between the two groups, qualitative analysis revealed that students in the experimental group were more proactive in identifying ethical issues, considering social impacts, and articulating a renewed understanding of the designer's societal role during the design process. The convergence of quantitative and qualitative data suggests that SSI instruction effectively fosters value transformation from cognition to design behavior by stimulating students' attention to scientific and ethical topics. These integrated findings indicate that SSI is not only a means of expanding disciplinary knowledge but also a powerful pedagogical path that shapes students' value orientations in design education.

### *Enhancement of Ethics Awareness*

SSI-based instruction introduced ethically charged scenarios such as "Would you be willing to live with an AI companion?" and "Can AI become a friend to humans?" to provoke moral reflection. Students engaged in group debates, stance analyses, and the formulation of ethical design principles. This task structure allowed them to


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reason morally and weigh values within socially authentic contexts, thereby internalizing ethical awareness at the cognitive level (Detert et al., 2008). For instance, one student mentioned users' potential emotional dependence on AI and proposed corresponding design responses. Such reflections show that students were beginning to move beyond considering design from merely functional or aesthetic perspectives. Instead, they began to reflect on user psychology, ethical risks, and societal impacts, and attempted ethical interventions through interface prompts or feature constraints (Stables, 2017).

This finding aligns with the ethics awareness development framework, which emphasizes that students' ethical sensitivity can be effectively triggered through problem-based and discussion-centered teaching approaches (Clarkeburn et al., 2002). Additionally, (Zeidler & Keefer, 2003) highlight that SSI instruction provides students with opportunities to practice moral reasoning, helping them form deeper ethical positions within science–society–technology conflicts. Thus, the ethical awareness presented in the experimental group's design work is not only an outcome of the instructional process but also a manifestation of students' internalized values. It can be concluded that SSI instruction in this study successfully built a bridge between ethical cognition, design thinking, and design expression, enabling students to translate ethical awareness into design action.

### *Enhancement of Social Responsibility*

The design task in the SSI-based instruction centered on the issue of "AI companions and the reconstruction of human relationships," guiding students to reflect on the societal and ethical implications of technological integration into daily life. Students were not only required to understand how AI systems function but also to consider their potential impact on vulnerable populations, such as the elderly, socially isolated individuals, and marginalized user groups (Papanek, 1985). For example, students reflected on how AI companions could provide care for older adults or assist users with hearing impairments. These reflections indicate that students began to perceive user experience as a mechanism for social response, actively expanding the definition of "designing for the user" to emphasize the broader societal relevance of design (Kouprie & Visser, 2009; Miaskiewicz & Kozar, 2011; Norman, 2005).

This finding aligns with the broader goals of science education, which aim to cultivate individuals with public consciousness and a sense of social responsibility (Herman et al., 2020; Hodson, 2003). It also echoes the core ideas of service-learning theory, which asserts that engaging students in real-world, socially oriented projects fosters stronger awareness, attitudes, and behaviors related to social responsibility (Eyler & Giles, 1999). In this study, students' sense of responsibility was reflected in specific design decisions—such as information presentation, interaction feedback, and emotional recognition—thereby enhancing both the depth of user experience and the social meaning of their design work.

Furthermore, the Reflective Reports revealed a shift in students' perception of their professional identity. Many moved from viewing themselves as task executors to embracing the role of socially responsible actors with moral judgment (Gasparski, 2003). As one student (S025) wrote, "AI has many advantages, but there are also risks in its use. As a designer, I should consider the negative impacts AI may have on society and respond through thoughtful design." This shift in awareness represents one of the key educational goals of SSI instruction: the cultivation of responsibility (Herman et al., 2020).

### *No Significant Difference in Scientific Accuracy*

SSI-based instruction adopts science-related ethical issues as an entry point, emphasizing technological understanding, value judgment, and reflection on societal challenges, rather than directly enhancing design techniques or formal expression (Zeidler et al., 2005). Therefore, the instructional focus is placed more on developing students' critical thinking and social awareness (Ban & Mahmud, 2023; Cavagnetto, 2010) rather than on immediately improving the complexity or creativity of their design outcomes. As one student noted in their reflection, "Although AI is everywhere now, it's still hard to fully understand the principles behind it." (S34) Such comments reflect that while students may have begun to recognize the social implications of technology, their grasp of scientific principles remains at a basic level, and their ability to translate this knowledge into specific design elements is still limited.

Constructivist learning emphasizes the construction of knowledge through hands-on practice (Narayan et al., 2013), but without sufficient time and continuous feedback, students' internalization of scientific concepts and improvement in design performance may be constrained (Bliss & Collingridge, 1993; Roediger & Karpicke, 2006). The lack of significant differences in scientific accuracy and creativity should not be interpreted as evidence against the effectiveness of SSI instruction. Instead, it suggests that such pedagogy is more focused—at least in the short


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term—on shaping students' values and awareness. To generate deeper transformations in design performance at the scientific and technical levels, longer-term, integrated science-design instruction may be necessary (Carpenter et al., 2022).

*Research Contributions*

This study, situated at the intersection of design education and science education, is the first to systematically integrate the SSI educational model into a vocational design curriculum. By employing a mixed-methods approach, the study evaluated the combined effects of SSI instruction on students' ethics awareness, social responsibility, scientific literacy, and design performance. The research offers meaningful contributions at both theoretical and practical levels.

On the theoretical level, this study expands the application boundaries of SSI instruction beyond STEM fields, demonstrating its effectiveness within design education—particularly in enhancing students' ethical reasoning and awareness of social responsibility. It highlights the integrative potential of interdisciplinary teaching models. Furthermore, by combining constructivist learning theory with SSI pedagogy, the study proposes a transformation pathway from value cognition to design practice. The analysis of qualitative reflective data also uncovers students' shifts in cognition and identity throughout the learning process, offering new dimensions and theoretical references for future studies.

On the practical level, this study developed and validated a design workshop model that embeds SSI topics, featuring structured phases including ethical conflict scenarios, position-based debate, design output, and Reflective Reports. This model is both replicable and operationalizable, offering a reference framework for curriculum reform in vocational and application-oriented design programs. Additionally, the rubric-based assessment tool developed in this study provides an empirical method to evaluate the ethical and societal value embedded in student design work.

*Limitations*

Several limitations should be acknowledged. First, the sample was drawn from design majors at a single vocational college in eastern China. Although the sample size met statistical requirements, the generalizability of the findings may be limited. Future studies should expand the geographical and disciplinary scope of the sample to test the broader applicability of the results. Second, the duration of the instructional intervention was limited to three days. While the findings revealed promising effects, the study did not examine the long-term impact of SSI instruction on students' value systems or professional behavior. Future research could adopt a longitudinal design to explore how SSI-based learning affects value internalization and professional development over time. Finally, although Reflective Reports served as an effective qualitative tool, the study did not incorporate other forms of qualitative data, such as teacher-student interaction or classroom observations. Future work could include interviews, observational data, and multi-source analysis to enhance the interpretive depth and completeness of the findings.

## Conclusions and Implications

This study integrated SSI into a three-day vocational design workshop and examined its effects on students' scientific literacy, ethics awareness, social responsibility, and design performance through a mixed-methods design. Compared with the business-as-usual design studio curriculum commonly adopted in the college (i.e., skills-oriented studio sessions that emphasize functionality and aesthetics), students who received SSI-based instruction showed statistically significant gains in ethics awareness and social responsibility. Their design work also achieved higher scores in ethical sensitivity and user experience. The absence of significant differences in scientific accuracy, creativity, and visual expression implies that SSI does not uniformly enhance every facet of design performance; these dimensions may require longer interventions or explicit scientific-skills scaffolding.

The findings demonstrate that SSI education is an effective strategy for cultivating designers who can make morally sound decisions and act with social responsibility. Embedding authentic ethical dilemmas, facilitating structured debates, and guiding students in Reflective Reports encouraged critical evaluation of design decisions and helped students reconceptualize their professional identity from "problem solvers" to "social actors with ethical responsibility."


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Practically, the study proposes a replicable workshop model—consisting of problem framing, ethical-conflict debate, prototype development, public feedback, and reflection—that program leaders can adapt to embed SSI topics in design curricula. The rubric created for this study, combining scientific and ethical criteria, offers a practical assessment tool for value-oriented design projects.

Because qualitative data were drawn solely from self-reported Reflective Reports, the findings may be subject to self-presentation bias. Future studies should triangulate data sources (e.g., teacher interviews, classroom observations, or design-process recordings) to enrich interpretation. Extending the intervention over a longer period, or coupling SSI tasks with explicit instruction in scientific principles and creative methods, may yield improvements in scientific accuracy, creativity, and visual expression.

## Declaration of Interest

The authors declare no competing interest.

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