# Athens Journal of Sciences

**Front Pages**

# Athens Journal of Sciences

*Published by the Athens Institute for Education and Research (ATINER)*

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The ***Athens Journal of Sciences (AJS)*** is an Open Access quarterly double-blind peer reviewed journal and considers papers from all areas of Natural & Formal Sciences, including papers on agriculture, computer science, environmental science, materials science, transportation science, chemistry, physics, mathematics and statistics, biology, geography, and earth science (geology, oceanography, astronomy, meteorology). Many of the papers published in this journal have been presented at the various conferences sponsored by the Natural & Formal Sciences Division of the Athens Institute for Education and Research (ATINER). All papers are subject to ATINER's Publication Ethical Policy and Statement.

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The current issue is the second of the tenth volume of the *Athens Journal of Sciences (AJS),* published by Natural & Formal Sciences Division of ATINER.

Gregory T. Papanikos, President, ATINER.

# Athens Institute for Education and Research
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**11th Annual International Conference on Chemistry**
**17-20 July 2023, Athens, Greece**

The Natural Sciences Unit of ATINER, will hold its **11th Annual International Conference on Chemistry, 17-20 July 2023, Athens, Greece** sponsored by the Athens Journal of Sciences. The aim of the conference is to bring together academics and researchers of all areas of chemistry and other related disciplines. You may participate as stream organizer, presenter of one paper, chair a session or observer. Please submit a proposal using the form available (https://www.atiner.gr/2023/FORM-CHE.doc).

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**Academic Members Responsible for the Conference**

- **Dr. Haiduke Sarafian**, Head, Natural Sciences Unit, ATINER & Professor of Physics and Endowed Chair of John T. and Paige S. Smith Professor of Science, Pennsylvania State University, USA.

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**Important Dates**

- Abstract Submission: **6 June 2023**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **19 June 2023**

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**Social and Educational Program**

The Social Program Emphasizes the Educational Aspect of the Academic Meetings of Atiner.

- Greek Night Entertainment (This is the official dinner of the conference)
- Athens Sightseeing: Old and New-An Educational Urban Walk
- Social Dinner
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**Conference Fees**

Conference fees vary from 400€ to 2000€
Details can be found at: https://www.atiner.gr/fees

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# Assessment of Computational Thinking:
# A Study of Preservice Teachers' Knowledge and Beliefs

*By Qing Li[*], Scot W. McNary[±] & Tracy Boyd[°]*

*Aiming to bridge the gap in the field of computational thinking and computing education, this study examines preservice teachers' knowledge of and self-efficacy related to CT assessment. It also develops a reliable instrument to understand the construct of teacher assessment of CT. Specifically, the research questions focus on investigating the extent of preservice teachers' knowledge and level of self-efficacy of CT assessment, and identifying the difference between demographic variables on teacher knowledge and self-efficacy related to CT assessment. Adopting a cross-sectional survey design, the participants were 182 preservice teachers. Both descriptive statistics and Exploratory Factor Analysis were used to analyze the data. The results show that the preservice teachers know little about how to use CT assessment to help students, and they believe they know even less about using specific assessment techniques to accomplish assessment.*

**Keywords:** *computational thinking, assessment, teacher knowledge, teacher self-efficacy*

## Introduction

This study aims to bridge the gap identified in the field of computational thinking (CT) and computing education by investigating preservice teacher (hereafter teachers) knowledge of and self-efficacy related to CT assessment. CT has been recognized as a new "basic skill" that all, not just a few, k-12 students need to master. A national push on teaching CT for all learners has started, as evidenced by a growing number of states adopting policies to support CT education as well as the increased funding for rigorous CT teacher preparation and professional development (https://code.org/advocacy/state-facts/MD.pdf).

A challenge to implement this policy, however, is the lack of qualified teachers, as illustrated by various documents including the report from the national organization Code.org (https://code.org/files/2018_state_of_cs.pdf). Preparing in-service teachers and pre-service teachers are essential to meet demand. In response to the shortage of qualified teachers, some institutions have begun to develop CS/CT preparation programs for prospective k-12 teachers.

Yet, a review of relevant literature identifies a significant gap: there is a lack of research on effective assessment related to CT education, especially for preservice education and in-service professional development (Tang et al. 2020). Limited, if any, research exists investigating assessment of CT learning in

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connection to pre-service/in service teacher education. This gap hampers the efforts of developing CT teacher preparation programs because assessment is a critical aspect of education. Assessment not only provides data to inform instructional practices, but also offers stakeholders' needed evidences to justify a range of decisions from funding policy to placing learners in different programs (Fischer 2010, Thomas 2012).

On the other hand, teacher knowledge and beliefs, including their self-efficacy, significantly influence their behaviors and effectiveness (Bray-Clark and Bates 2003). It is well established in the literature that teacher self-efficacy is positively correlated to teaching methodologies and student achievement (Kaya et al. 2020). According to Bender and colleagues (Bender et al. 2016), CS/CT teachers face challenges, including but not limited to, teachers' beliefs about their insufficient qualification and lack of preparation, their lack of opportunities to collaborate with peers; high pressure to remain current with the ever changing technologies. These authors posit that teacher beliefs not only play an important role in addressing such challenges, but also should be carefully considered when developing CS/CT teacher preparation programs. Several studies, including a couple of literature review papers (Kallia 2017, Tang et al. 2020) which have analyzed hundreds of studies published from 2001-2019 focusing on assessment of computing courses, discovered that though some attention has focused on assessment in computing courses, there is a dire need for the advancement of knowledge on assessment in CS/CT teacher preparation.

Similarly, Yadav and colleagues (Yadav et al. 2015) have argued that understanding teachers' experience and beliefs related to CS/CT education is a critical first step towards the development of effective assessment strategies and approaches. The review of the existing literature shows the lack of a psychometrically sound instrument that assesses teachers' knowledge and self-efficacy of assessment connected to CT. This study, therefore, attempts to address the need by enhancing our understanding of computing education assessment focusing on teacher knowledge and beliefs. Another purpose of this work is to help develop a reliable instrument to understand the construct of teacher assessment of CT.


**Related Literature**

The importance of assessment is unquestionable. As a comprehensive data gathering and evaluation process, assessment provides teachers useful information to improve their teaching. To optimize the development of schooling and learning, assessment practices need to meet the highest standards (Jaipal-Jamani and Angeli 2017).

Teacher assessment knowledge embodies a synthesis of their content and pedagogical knowledge (Millay 2018). Teachers must realize that merely presenting information is not enough to ensure learning, and effective learning is a complex interplay of the teaching process and its outcomes (Bond 1995). When assessing learning, teachers are required to align specific goals, determine the extent to

which anticipated outcomes are achieved, and make appropriate decisions accordingly (Gonzales and Callueng 2014). Further, better understanding of tools and strategies for assessment directly enhances teachers' development in general, because effective assessment produces more helpful data to improve teaching practices (Henze et al. 2008).

Merely equipping teachers with the needed knowledge and skills, however, do not guarantee successful assessment practice because their beliefs, including their self-efficacy, also largely affect their behaviors. Self-efficacy theory, originally developed by Bandura (1977), points to the predictive value of teachers' confidence in connection with the success of their performance. That is, whether a teacher would successfully apply certain knowledge or skills is greatly dependent on their beliefs in their competency to implement such skills.

*Assessment and CT*

Although CT has gained increased attention in recent years and numerous studies have published focusing on various aspects of CT education, less work has focused on assessment of CT. The research on assessments related to CT works to fill the gaps of student assessment. For instance, Relkin et al. (2020) designed "unplugged" CT assessments for students, aged five through nine. Similarly, Polat et al. (2021) researched the need for evaluating secondary school students through a range of perspectives to provide more comprehensive CT assessments. Some used standardized multiple-choice or performance assessment based on the analysis of students' developed coding artifacts (Mouza et al. 2017, Tang et al. 2020). Even though these niche areas beneficial, to effectively incorporate CT into a K–12 curriculum, it is necessary to provide teachers with guidance for how to assess it (Grover and Pea 2013). Additionally, teachers must develop personal CT competency for their professional work to certify achievement of learning objectives (Menon et al. 2019).

In a recent paper, Tang and colleagues (Tang et al. 2020) systematically reviewed 96 studies of CT assessment between 2010-2019. Focused on educational context, assessment constructs and types, and reliability and validity evidences, they found that only 15% of the studies examined teacher education, leading to their conclusion that more studies are needed at this level. They also found that all of these studies focused on examining and assessing teachers' understanding of CT and related beliefs, with virtually no study explored teacher knowledge of or beliefs about CT assessment. Another review study (Wang et al. 2021) focused on integrating CT in STEM education. Their semi-systematic literature review of 55 empirical studies on this topic showed that the assessment of student learning in CT integration into STEM subjects adopted different approaches with various objectives.

For example, Adler and Kim (2018) studied preservice teachers learning of CT via modeling and simulation in a science methods course. Their survey results showed that the preservice teachers learned CT and intended to integrate CT into their future teaching. Another study (Cetin 2016) examined the effect of Scratch-based instruction on preservice teachers' understanding of basic programming

concepts and their attitudes toward program. Adopting a mixed method design, the results showed the Scratch-based instruction allowed the development of a meaningful learning environment to help preservice teachers understand basic computing concepts.

A related study (Jaipal-Jamani and Angeli 2017) examined the impact of robotics on preservice teachers. The 21 elementary preservice teachers took a science methods course in which robotics were integrated. The results showed a significant knowledge gain in science concepts and basic CT skills, and increased both the preservice teachers' interest in robotics and their self-efficacy in using robotics for instructional purposes.

Some studies examined the effects of different programming templates on preservice teachers' learning of CT. A study (Pala and Mıhçı Türker 2019) examined the impact of Arduino IDE and C++ programming languages on preservice teachers' knowledge. Using the CT Skills Scale survey, their results showed a knowledge gain in the Arduino IDE group in creativity, algorithmic thinking, critical thinking, but not problem solving or cooperativity factors. In addition, no gain was identified in the C++ group.

Another line of research is to automate the assessment of learner produced artifacts. Based on the framework of Brennan and Resnick (2012), several technology tools were developed, including *Hairball* and *Dr. Scratch* (Boe et al. 2013, Moreno-León and Robles 2015). These software templates enabled automatic evaluation of CT skills through analysis of learner generated programming products. Li and Pustaka (2020) examined the impact of educational game development experience on teachers' pedagogical and content knowledge related to CT. Using Dr. Scratch, they quantitatively analyzed the games created by 80 educators and concluded that game creation allowed teachers to develop an overall proficiency in CT skills.

*Teacher Beliefs*

Moving from teacher knowledge to teacher beliefs, though limited, some studies have examined preservice teachers' perceptions and others investigated effects of interventions on them, usually through surveys or interviews. These investigations have focused on teacher attitudes toward CT and CT teaching, as well as their confidence in teaching CT.

For instance, an Australian study (Bower and Falkner 2015) examined the CT related perceptions of 44 preservice teachers (33 females, 11 males) who were enrolled in an education course. The results showed that most preservice teachers had misconceptions, ranging from treating CT as general technology use like searching internet, to equating CT integrated teaching to using technology in classrooms. A majority of them lacked confidence in teaching CT, while several were overconfident with associated misunderstanding. They welcomed opportunities to gain content, pedagogical and technological knowledge related to CT teaching.

A Canadian study (Gadanidis et al. 2017) explored the experience of 143 preservice elementary teachers learning CT in a math education course. The blended nine-week, 18-hour course aimed to help teachers gain content and

pedagogical knowledge related to mathematics teaching with CT. Through analysis of teacher reflection and online discussions, the case study found that teachers developed some new ideas related to CT and the course helped reduce teacher apprehension towards CT in mathematics teaching and learning.

A review study (Cabrera 2019) examined 24 existing papers and identified that teachers tended to hold preconceptions impacting their understanding of CT. Specifically, they often equate CT to one of the following concepts: 1) technology integration, 2) coding, 3) problem solving, and 4) "thinking like a computer". Additional teachers might believe that CT should not be part of k-12 education for reasons ranged from CT is too difficult to learn, to certain student groups could not manage to acquire such skill, to conflicts with the curriculum, to constraints such as time limitation and instructional structure of schools.

In summary, while CT has gained increasing attention from various groups, studies that focused on assessment in teacher education are still relatively limited. Amongst this limited exploration, even less, if any, work has examined teacher knowledge or beliefs related to assessment of CT. To bridge this gap, this study investigates the knowledge and self-efficacy of preservice teachers connected to CT assessment.

## *Research Questions*

Grounded in constructivism, this study considers assessment beyond the idea of "assessment of learning". Rather, assessment is considered for learning, of learning, and as *learning*. Sound assessment, therefore, requires teachers' deep understanding and a high level of self-efficacy of the specific assessment tools, techniques and strategies. Specifically, this is guided by the following research questions:

1. To what extent do preservice teachers know about using CT assessment?
2. What level of self-efficacy do preservice teachers hold about CT assessment?
3. Are there differences between levels of salient demographic variables (i.e., gender, ethnic identity, program of study) on derived factor scores of teacher knowledge and self-efficacy related to CT assessment?

## **Methods**

### *Participants*

Adopting a cross-sectional survey design, the participants were 182 preservice teachers enrolled in a university in the mid-Atlantic region of the United States. Nearly three-quarters of respondents were females, and two thirds were White. The average age among those who reported it was 21.6 (SD = 3.5, N = 168). One third of the participants enrolled in the secondary program. Among the participants, about 45% were juniors and close to half were the combination of sophomore and senior students.

There was some variety in concentrations represented although Social Studies (36%), English (31%), Special Education (30%), and Early Childhood (28%) were the most frequently endorsed. About 14% said "Yes" and another 36% said "Maybe" when asked whether they would be interested in teaching computer science after graduation. See Table 1 and Table 2 for a complete description of participants.

**Table 1.** *Participants' Demographics*

| Student demographic variable | N = 182(%) |
|---|---|
| Gender | |
| Female | 135 (75) |
| Male | 41 (23) |
| Prefer not say/Missing | 3 (2) |
| Race/Ethnicity | |
| White | 105 (66) |
| Black | 22 (14) |
| Hispanic, mixed, Native American | 16 (10) |
| Asian | 10 (6) |
| Other | 5 (3) |
| Program | |
| Secondary | 55 (33) |
| Special Education | 36 (22) |
| Early Childhood | 31 (19) |
| Elementary | 26 (16) |
| Middle School | 11 (7) |
| Early Childhood/Special Education | 8 (5) |
| Year | |
| Freshman | 6 (3) |
| Sophomore | 37 (21) |
| Junior | 80 (45) |
| Senior | 47 (27) |
| Graduate/other | 7 (4) |
| | N/Mean/SD |
| Age | 168/21.59/3.53 |
| Number of prior Math/Computer Science Courses | 151/9.55/11.28 |

**Table 2.** *Participants' Characteristics*

| Student characteristic | Yes (%) | No (%) | Maybe (%) |
|---|---|---|---|
| Interested in teaching CS/CT | 8 (14) | 39 (51) | 21 (36) |
| Concentration | | | |
| -Social Studies | 52 (36) | 92 (64) | |
| -English | 45 (31) | 99 (69) | |
| -Special Ed | 43 (30) | 101 (70) | |
| -ECE | 40 (28) | 104 (72) | |
| -Math | 19 (13) | 125 (87) | |
| -Science | 16 (11) | 128 (89) | |

Percentage may not add to 100% due to students with double concentrations.

*Instrument & Analysis*

Adapted from the work of Gonzales and Callueng (2014), a three-step procedure was used to develop this survey. First, based on the existing literature, the initial instrument was created. Second, a group of experts were asked to judge the suitability and accuracy of the questions, as well as the general organization of the instrument. Based on the feedback, we adjusted the instrument, eliminating inappropriate items and reorganizing remaining ones. One suggestion adopted was moving the demographic information section from the beginning to the end because research shows that putting them up front may trigger stereotype threat (Cohoon et al. 2011). Third, a group of five students who represented the targeted sample were asked to pilot the instrument. The data collected allowed us to further modify the instrument. The significant changes on the instrument concerned rewording and additional detail for some items to avoid confusion. This modified instrument became the final survey questionnaire used for the study.

The survey consisted of a total of 33 items. The first part, containing 10 questions, asked teacher knowledge about using CT assessment. The second part, with 16 questions, evaluated teachers' self-efficacy about assessment practices and strategies. The last part, a total of seven questions, asked about teachers' demographic information.

Means, SDs, and frequency of selected responses were computed to address the research questions one and two of this study. To answer the research question three, factor analysis was conducted to determine the structural characteristics of the measure. All analyses were conducted using R [Version 4.0.3; R Core Team (2021)] and the R-package psych [Version 2.0.12; Revelle (2020)].

**Results**

*CT Assessment Knowledge*

The first research question focused on teachers' knowledge of CT assessment. This was investigated from two perspectives: 1). Teacher knowledge about using CT assessment and 2). Their knowledge of specific types of CT assessment.

First, pre-service teachers were asked how much they knew about using assessment of CT knowledge for various purposes. The scale used to record responses was: 1 = no knowledge 2 = little knowledge 3 = some knowledge 4 = know well 5 = know very well. On average, survey respondents responded they did not know how to do any of the tasks well as means were below 2.0 ("little knowledge") for all items, and no more than 12% of the sample claimed they knew any task well/very well (see Table 3).

**Table 3.** *Pre-service Teachers Knowledge about CT Assessment (N = 182)*

| How much do you know about using CT assessment to: | Mean | SD | Know well or Very Well *n* (%) |
|---|---|---|---|
| 1. guide students to set their goals and monitor their own CT learning progress? | 1.98 | 0.94 | 9 (5.0) |
| 2. demonstrate to students how to do self-assessment of their CT learning? | 1.92 | 0.95 | 8 (4.5) |
| 3. determine how students can learn CT on their own in class? | 1.86 | 0.94 | 11 (6.1) |
| 4. help students develop clear criteria of good CT learning? | 1.89 | 0.96 | 11 (6.1) |
| 5. set the criteria for students to assess their own performance related to CT in class? | 1.86 | 0.97 | 13 (7.3) |
| 6. measure extent of CT learning at the end of a lesson or subject? | 1.92 | 1.04 | 18 (10.2) |
| 7. make final decisions about the level of CT learning that students achieved at the end of a lesson or subject? | 1.85 | 1.01 | 15 (8.4) |
| 8. help students improve their CT learning process and class performance? | 1.99 | 1.05 | 17 (9.5) |
| 9. assist students to determine their CT learning strengths and weaknesses in class? | 1.97 | 1.06 | 20 (11.2) |
| 10. identify better CT learning opportunities for students in class? | 1.93 | 1.09 | 16 (8.9) |

Note: 1 = no knowledge 2 = little knowledge 3 = some knowledge 4 = know well 5 = know very well.

A second set of questions concerned specific types of assessment methods used to assess CT ability and knowledge. The same 1-5 response scale used for CT Assessment Knowledge was used for these items. As indicated in Table 2, the means are quite low—none exceed 2 ("little knowledge") on the five-point response scale. Only a small percentage of teachers (4-8% "know well" or "very well") claimed knowledge of any of the six specific assessment techniques inquired about. What is most notable is that for all six assessment methods, respondents' mean response was less than the CT Assessment knowledge items. That suggests that respondents believe their knowledge about specific techniques is less than their knowledge about general use of assessment for CT. Put another way, although respondents felt they knew little about how to help students assess their own CT learning, they believe they know even less about using specific assessment techniques (e.g., Artifact Based Interviews) to accomplish assessments. This suggests there is room to develop knowledge about all six assessment techniques. See Table 4 for details.

**Table 4.** *Preservice Teachers Knowledge about Types of Assessment (N = 182)*

| How much do you know about: | Mean | SD | Know Well or Very Well *n* (%) |
|---|---|---|---|
| 1. using Artifact-Based Interviews to assess students' CT practices? | 1.76 | 0.94 | 11 (6.1) |
| 2. creating appropriate Artifact-Based Interviews questions in order to assess students' CT practices? | 1.75 | 0.93 | 10 (5.6) |
| 3. using Design Scenarios to assess students' CT practices? | 1.77 | 0.92 | 9 (5.1) |
| 4. creating appropriate Design Scenarios in order to assess students' CT practices? | 1.77 | 0.91 | 10 (5.6) |
| 5. using Learner Documentation to assess students' CT practices? | 1.82 | 1.01 | 14 (7.8) |
| 6. creating appropriate Learner Documentation in order to assess students' CT practices? | 1.77 | 0.94 | 8 (4.5) |

Note: 1 = no knowledge 2 = little knowledge 3 = some knowledge 4 = know well 5 = know very well.

*Self-Efficacy of CT Assessment*

The second research question aimed to examine teachers' beliefs, specifically their self-efficacy, about CT assessment. Preservice teachers were asked to judge their own ability to develop and implement CT assessment. The scale use for these items ranged from 1 = Strongly disagree to 5 = Strongly agree. A score of 3 indicated a Neutral response to the item. All but two of the items had means less than 3, suggesting that the average response was to disagree. Items such as "I can develop appropriate CT assessment plans" (M = 2.25 SD = 1.12) and "I can create good rubrics for CT assessment" (M = 2.29 SD = 1.12) were the lowest rated, indicating general disagreement with these claims and therefore relatively lower efficacy for these tasks compared to the others. These items relate to planning for CT assessment and are similar to the findings about setting criteria for students' learning in Table 2 above. The two items for which respondents produced an average exceeding 3 were reverse-scored items ("I do not know how to construct objective tests of CT" and "I am not confident in reporting CT assessment results") and 54% and 39% of the sample agreed with these statements, respectively. These responses are consistent with the remaining items suggesting that many respondents do not feel capable of developing and implementing assessments of students CT learning. One item that was reverse-scored, "I am not good at scoring and marking CT tests and assessment tools" resulted in a mean of less than 3, suggesting a relative strength for at least some respondents. Of all the tasks, respondents felt most efficacious about scoring and marking tests, yet still about 30% of the sample agreed they were not good at this task. See Table 5 for details.

**Table 5.** *Respondent Efficacy Judgment for Specific CT Assessment Tasks (N = 182)*

| Rate your degree of agreement with this statement: | Mean | SD | Agree or strongly agree *n* (%) |
|---|---|---|---|
| 1. "I can write good learning outcomes of CT." | 2.36 | 1.09 | 27 (15.2) |
| 2. "I do not know how to construct objective tests of CT."* | 3.38 | 1.36 | 96 (53.9) |
| 3. "I can define tasks for performance assessment (i.e. assess students by asking them to perform tasks) of CT." | 2.38 | 1.12 | 30 (16.8) |
| 4. "I can choose the most appropriate item type (e.g. multiple choice, true/false) for a CT test." | 2.66 | 1.26 | 54 (30.2) |
| 5. "I can ask essay questions for CT assessment." | 2.35 | 1.17 | 35 (19.7) |
| 6.:"I can create good rubrics for CT assessment." | 2.29 | 1.12 | 29 (16.3) |
| 7. "I can develop appropriate CT assessment plans." | 2.25 | 1.12 | 28 (15.6) |
| 8. "I am not good at scoring and marking CT tests and assessment tools."* | 2.90 | 1.29 | 55 (30.7) |
| 9. "I can link learning outcomes with CT assessment processes." | 2.31 | 1.09 | 27 (15.1) |
| 10. "I am not confident in reporting CT assessment results."* | 3.18 | 1.35 | 70 (39.1) |

Note: 1=Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree. * indicates a reverse-scored item.

*Demographic Variables, Knowledge & Self-Efficacy*

The third research question examined possible differences between demographic variables on teacher knowledge and self-efficacy related to CT assessment. The 26 items across the three proposed scales were submitted to an Exploratory Factor Analysis (EFA). Preliminary measures of factorability suggested item intercorrelations could be factored; the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (MSA) was 0.93 for the correlation matrix (0.70 is conventionally considered adequate) and MSAs for items ranged between 0.68-0.97; Bartlett's test of Sphericity was statistically significant, $X^2$ (325) = 5668.90; $p < 0.001$, implying the correlation matrix was not an identity matrix and therefore presumably containing at least one factor. The scree plot (Figure 1), parallel analysis (Figure 2), and Velicer's MAP suggested that four factors were reasonable to extract, and all four had eigenvalues that exceeded 1.0, the Kaiser criterion. Collectively, these four factors explained 69% of the total variance. The first three factors explained 63%. That is, the factor analysis produce 3 factors that fit the data well.

**Figure 1.** *Scree Plot*
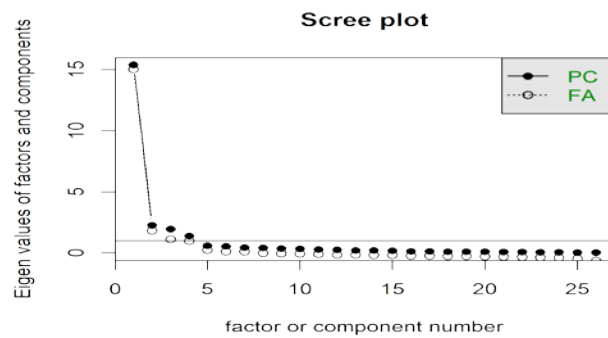


**Figure 2.** *Parallel Analysis*
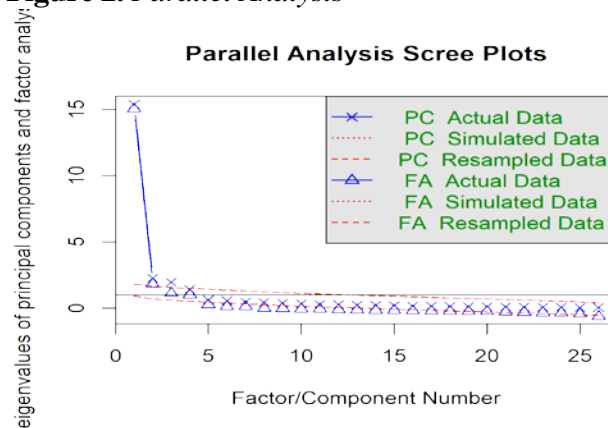


The four factors were rotated obliquely via Oblimin rotation which allows factors to correlate among themselves. Loadings for the four factors on each variable are shown in Table 6 and a path diagram of the measurement model is shown in Figure 3.

**Table 6.** *Factor Loadings for Four Factors*

| Item | Assessment Knowledge | Assessment Technique Knowledge | Assessment Self-Efficacy | Reverse-scored Assessment Self-Efficacy items | communality |
|---|---|---|---|---|---|
| Q1[1] | 0.74 | | 0.16 | | 0.69 |
| Q2[1] | 0.86 | | | | 0.71 |
| Q3[1] | 0.87 | -0.16 | 0.14 | | 0.75 |
| Q4[1] | 0.83 | | | | 0.76 |
| Q5[1] | 0.91 | | | | 0.85 |
| Q6[2] | 0.79 | | | | 0.81 |
| Q7[2] | 0.88 | | | | 0.79 |
| Q8[3] | 0.90 | | | | 0.84 |
| Q9[3] | 0.87 | | | | 0.85 |
| Q10[3] | 0.68 | | 0.21 | | 0.82 |
| Q17 | 0.24 | 0.65 | | | 0.76 |
| Q19 | 0.20 | 0.68 | | | 0.77 |
| Q20 | | 0.88 | | | 0.82 |
| Q21 | | 0.92 | | | 0.82 |
| Q22 | | 0.92 | | | 0.79 |
| Q23 | | 0.90 | | | 0.77 |

| | | | | |
|---|---|---|---|---|
| Q25 | | 0.90 | | 0.68 |
| Q11 | -0.11 | | 0.91 | 0.50 |
| Q12 | | | 0.93 | 0.65 |
| Q13 | | | 0.84 | 0.78 |
| Q14 | 0.15 | | 0.76 | 0.84 |
| Q15 | 0.20 | | 0.69 | 0.84 |
| Q16 | 0.19 | | 0.67 | 0.88 |
| Q18r | | | | 0.69 | 0.44 |
| Q24r | | | | 0.67 | 0.80 |
| Q26r | | | | 0.90 | 0.80 |
| Eigenvalue | 7.94 | 5.48 | 4.62 | 1.80 | |
| Cronbach's alpha | 0.97 | 0.96 | 0.88 | | |
| Factor correlations | | | | | |
| Assessment Technique Knowledge | 0.65 | | | | |
| Assessment Self-Efficacy | 0.73 | 0.59 | | | |
| Reverse-Scored Assessment Self-Efficacy | 0.21 | 0.17 | 0.21 | | |

*Note*: superscripts[1,2,3] refer to factors in Gonzales and Callueng (2014).

**Figure 3.** *Measurement Model*



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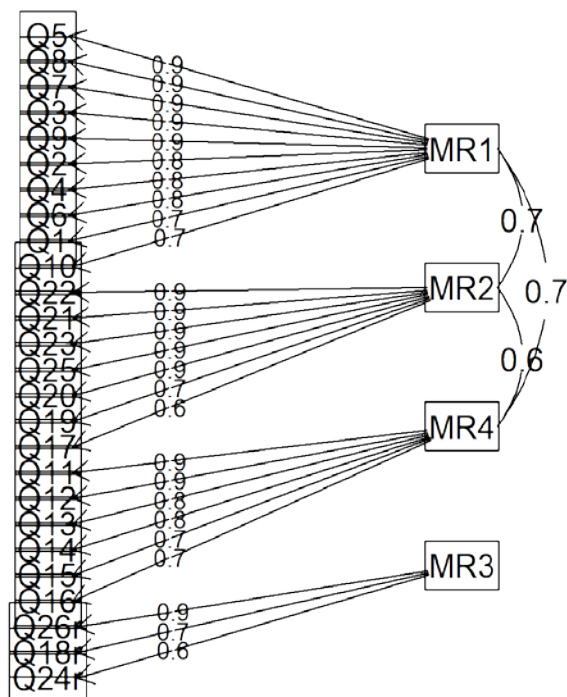
Communalities were high (> 0.50) for all but items Q11 and Q18, suggesting common factors explain more than half the items variance for almost all items. The factor loadings show that the conceptual grouping of the items was very similar to the empirical grouping of them. Where cross-loadings occurred there were small (≤ 0.20; see italicized loadings in Table 5), and other loadings on factors exceeded 0.60. There were three exceptions to the otherwise tidy factor structure, and that was the clustering of the three reverse-scored Assessment Efficacy items. These items did not correlate very highly with the other factors and seem to be related mainly because of the form of the questions "I do not know…", "I am not good at….", "I am not confident…". For this reason, these items were not used to create the Assessment Efficacy factor and only the seven items that remained in that scale were used.

Factor scores were computed so that comparisons of sub-groups of respondents could be conducted. Factor score means for specific subgroups are shown in Table 7. Sample sizes vary considerably between subgroups reducing power for many comparisons, and significance tests are of questionable value for comparisons among groups in a study whose purpose was not to conduct group contrasts. Instead, group comparisons would be more useful once conducted on a new sample designed to represent demographic balance in the desired population. However, it may be useful to note several patterns of subgroup differences.

**Table 7.** *Factor Scores by Student Group*

| Group1 | n | Assessment Knowledge | | | Assessment Technique Knowledge | | | Assessment Efficacy | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Median | Mean | SD | Median | Mean | SD | Median |
| Gender | | | | | | | | | | |
| Male | 41 | 1.95 | 0.90 | 2.00 | 1.87 | 0.98 | 1.50 | 2.46 | 1.10 | 2.57 |
| Female | 135 | 1.89 | 0.89 | 1.80 | 1.73 | 0.81 | 1.50 | 2.35 | 1.00 | 2.43 |
| Prefer not to say/Other | 3 | 2.10 | 1.04 | 1.60 | 2.06 | 1.18 | 1.83 | 2.24 | 0.54 | 2.00 |
| Program | | | | | | | | | | |
| Early childhood | 31 | 2.07 | 1.04 | 1.70 | 1.83 | 0.93 | 1.67 | 2.42 | 0.89 | 2.43 |
| Elementary | 26 | 1.90 | 0.86 | 2.00 | 1.69 | 0.68 | 1.58 | 2.54 | 0.88 | 2.57 |
| Middle school | 11 | 2.49 | 0.76 | 2.40 | 2.48 | 0.92 | 2.17 | 3.09 | 0.86 | 3.43 |
| Secondary | 55 | 1.76 | 0.93 | 1.30 | 1.75 | 0.92 | 1.33 | 2.35 | 1.16 | 2.43 |
| Special education | 36 | 1.91 | 0.77 | 2.00 | 1.66 | 0.77 | 1.33 | 2.13 | 0.93 | 2.07 |
| Early Childhood/Special Education | 8 | 1.39 | 0.55 | 1.10 | 1.31 | 0.46 | 1.00 | 1.77 | 1.15 | 1.07 |
| Stage | | | | | | | | | | |
| Freshman | 6 | 1.98 | 1.02 | 1.65 | 1.94 | 1.00 | 1.75 | 2.55 | 1.05 | 2.43 |
| Sophomore | 37 | 1.61 | 0.76 | 1.20 | 1.53 | 0.63 | 1.17 | 2.32 | 0.96 | 2.43 |
| Junior | 80 | 2.20 | 0.92 | 2.10 | 1.96 | 0.93 | 1.71 | 2.68 | 0.96 | 3.00 |
| Senior | 47 | 1.74 | 0.80 | 1.60 | 1.67 | 0.83 | 1.25 | 1.97 | 1.02 | 1.71 |
| Other | 1 | 1.00 | NA | 1.00 | 1.00 | NA | 1.00 | 1.86 | NA | 1.86 |
| Graduate | 6 | 1.48 | 0.85 | 1.20 | 1.58 | 0.88 | 1.33 | 1.79 | 1.18 | 1.29 |
| Ethnicity | | | | | | | | | | |
| Asian | 10 | 1.66 | 0.86 | 1.20 | 1.52 | 0.78 | 1.00 | 2.34 | 1.18 | 2.21 |
| Black | 22 | 2.09 | 1.08 | 1.90 | 1.83 | 0.89 | 1.50 | 2.49 | 1.07 | 2.43 |
| Hispanic | 9 | 2.00 | 1.05 | 2.00 | 1.83 | 0.95 | 1.33 | 2.21 | 0.78 | 2.29 |
| Mixed | 5 | 1.76 | 1.11 | 1.20 | 1.67 | 0.92 | 1.00 | 2.29 | 1.23 | 2.57 |
| Native American | 2 | 2.05 | 1.34 | 2.05 | 2.33 | 1.18 | 2.33 | 3.64 | 0.51 | 3.64 |
| Other | 5 | 2.32 | 1.43 | 2.00 | 2.37 | 1.47 | 2.00 | 2.69 | 1.54 | 3.71 |

| White | 105 | 1.85 | 0.81 | 1.80 | 1.70 | 0.82 | 1.33 | 2.34 | 1.00 | 2.43 |
|---|---|---|---|---|---|---|---|---|---|---|
| Interested in Teaching Math/Comp Sci? | | | | | | | | | | |
| Yes | 8 | 2.38 | 1.20 | 2.30 | 2.50 | 1.33 | 2.92 | 2.45 | 1.20 | 2.93 |
| No | 30 | 1.80 | 0.80 | 1.65 | 1.92 | 0.88 | 1.92 | 2.40 | 1.16 | 2.64 |
| Maybe | 21 | 1.77 | 0.90 | 1.30 | 1.74 | 0.89 | 1.50 | 2.58 | 1.20 | 2.86 |
| Overall | 182 | 1.92 | 0.89 | 2.00 | 1.76 | 0.85 | 1.50 | 2.37 | 1.01 | 2.43 |

It appears that means for males exceeded females for all three factors, and middle school program respondents exceeded all other respondents for all three factors. That is, on average, males, compared to females, reported higher level of Assessment Knowledge, Assessment Technique knowledge, and self-efficacy. Similarly those enrolled in middle school programs, compared to those in other programs, believed they had higher levels of knowledge and efficacy. Junior respondents' mean scores exceeded other respondents' mean scores for the Assessment Knowledge and Assessment Technique Knowledge factors, and all but Freshman respondents (n = 6) for the Assessment Efficacy factor.

Non-white respondents reported more knowledge and efficacy than White and Asian respondents, e.g., Black > Hispanic > White > Asian for the Assessment Knowledge factor; Black and Hispanic respondents' mean > White > Asian respondent's means for the Assessment Technique Knowledge factor; Black respondent means > White = Asian > Hispanic respondent means for the Assessment Efficacy factor.

Respondents who acknowledged they are interested in teaching Math/ Computer science classes reported higher means than those not interested, or who said they may be for the Assessment Knowledge and Assessment Technique Knowledge factors. Respondents who only maybe interested in teaching Math/ Computer Science reported larger Assessment Efficacy factor means than others. The sample size for respondents answering this question was fewer than half (n = 59) of all responses so it is difficult to interpret this pattern.

Table 8 shows correlations between the factor scores and respondent age and number of college credits in math or computer science coursework. Correlations are small to moderate in size, and statistically significant for the math/computer science coursework variable and Assessment Knowledge, $r(149) = 0.21$, $p < 0.05$, and Assessment Efficacy, $r(149) = 0.19$, $p < 0.05$. It shows that the higher number of math and or computer science credit hours, the more likely the participants believed they had more assessment knowledge and high levels of self-efficacy of CT assessment.

**Table 8.** *Correlations of Age and Hours in Computer Classes with Factor Scores*

| | N | Assessment Knowledge | Assessment Technique Knowledge | Assessment Efficacy |
|---|---|---|---|---|
| Age | 168 | 0.11 | 0.12 | 0.08 |
| Math/Comp Sci. credit hours | 151 | 0.21* | 0.15 | 0.19* |

*Note:* *p < 0.05.

**Discussion and Conclusions**

Despite the growing interest in CT education, studies on assessment of CT, especially related to teacher preparations is scarce. The current study addresses this gap through the examination of teacher knowledge and self-efficacy related to CT assessment. Outcomes from this research provide valuable information to deepen our understanding of effective ways to assess computing education. This can also inform teacher education in designing appropriate CS/CT education programs as well as useful assessment tools.

Shedding lights on the field of assessment in relation to CS/CT education, this study have several results worthy of further discussion. The most significant finding perhaps is that a vast majority of the teachers have limited knowledge and low self-efficacy related to CT/CS assessment. On average, the teachers do not know how to do any of the CT assessment tasks, only one in ten teachers claim they know any of the assessment tasks well. With respect to specific types of and self-efficacy related to CT assessment, the results are similar. In other words, teachers know little about how to use CT assessment to help students, and they believe they know even less about using specific assessment techniques to accomplish assessment. This is astonishing because it demonstrates how our preservice teachers are not prepared to integrate CT and computing into their practice.

Various researchers (Barr and Stephenson 2011, Li 2021) have argued that since CT is a problem solving skill used in all disciplines, CT should be integrated in all subjects rather than just in stand-alone CS courses. Thus, most, if not all, teachers should be prepared to integrate CT into their subject areas (Barr and Stephenson 2011, Yeni et al. 2021). Yet our results show that a vast majority of our preservice teachers are not equipped with the needed knowledge and skills to do so. It is shocking, but perhaps not surprising. Assessment has long been treated as a less pressing topic to teach in teacher education, usually because of the tight schedule of teacher preparation programs. Similarly, CT/CS training is usually not part of preservice teacher programs owning largely to its resent introduction. Preservice teachers' lack of knowledge and low level of self-efficacy in CT assessment suggests unless changes in teacher preparation of CS/CT instruction are made, they will struggle to make instructional decisions that align with best practices.

Another important contribution of this study comes from the results of the exploratory factor analysis. As discussed earlier, there is a dire need of reliable instruments to measure the construct of teacher assessment of CT. Our results show that the tool we developed is a psychometrically sound instrument to understand teacher knowledge and self-efficacy of assessment connected to CT which addresses the gap identified in the existing literature. The ten Assessment Knowledge items were adapted from Gonzales and Callueng (2014). In their EFA, the ten items were spread across three factors, unlike the current findings in which all ten Assessment Knowledge items cohered on one factor. However, the five items on the Assessment Knowledge factor share with Gonzales and Callueng's (2014) Assessment as learning factor have similarly high factor loadings and high

communalities. There are at least four reasons for why there is diverge in factor loading among the remaining five items: the first reason could be the adaptation of the items from a general assessment context to the Computational Thinking assessment context. Secondly, the samples differ in age and background: Gonzales and Calleung's sample consisted of practicing teachers whereas the current sample is completely pre-service teachers. Thirdly, cultural differences between teacher preparation, classroom experience, and educational systems between Filipino teachers and US teachers may result in different experiences. Fourth, each survey appeared with different items for different purposes and the context of the survey may invoke different response styles and knowledge schema. Some combination of these reasons may also apply, thereby producing different item intercorrelations between the samples.

This study has practical implications as well. As argued by Yadav and colleagues (Yadav et al. 2017), teacher education programs provide an opportune time to help teachers develop competencies to embed CT in their future classrooms. In addition, previous work (Leonard et al. 2018) has demonstrated that carefully designed instructional practice can increase teachers' self-efficacy beliefs in relation to CT knowledge. Given the importance of assessment in teaching and learning of any subject, CS/CT included, our results suggest that it is imperative that preservice teachers are offered opportunities to learn the needed knowledge and skills related to CT assessment. Recognizing how busy preservice teacher programs are, we recommend that assessment to be integrated into the existing coursework rather than standalone assessment courses. For instance, the methods courses and the existing educational technology courses in teacher education programs are a natural fit for exposing CT assessment knowledge to teachers.

Like any educational research, this study has its own limitations. First, the sample is preservice teachers who have very limited classroom experiences. Future research are recommended to examine other groups including in service teachers. Secondly, the data is collected from students enrolled a university located in an urban city. Generation of the results to other populations need to take cautious.

Although CT education has gained some traction in educational research, the exploration of CT assessment related to teachers are extremely limited. Since assessment plays such a critical role in teaching and learning, it is essential that researchers pay close attention to this area. Until we have a deep understanding of CT assessment and teacher education, we can start designing and developing programs that best prepare our teachers to teach CT.

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# Artificial Intelligence Utilization in Libraries

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*Artificial intelligence is becoming more and more crucial each passing day.*
*This study initially will present artificial intelligence utilization in libraries. In*
*1950, Alan Turing came up with the idea that computers might be able to*
*imitate human behavior. According to Turing, artificial intelligence could*
*analyze texts, make modelling the knowledge to help decision-making,*
*reproduce a standard reasoning and use this information to make decisions and*
*to produce knowledge thanks to machine learning. In this research, a literature*
*review is conducted concerning different aspects of the subject. This study will*
*lead to better focus on different scientific point of view about the artificial*
*intelligence.*

**Keywords:** *artificial intelligence, libraries, technology, digital transformation,*
*smart libraries*

## Introduction

Artificial intelligence or AI is a sub-branch of computer science built on computing machines and systems that can mimic human learning and decision-making (Castro & New, 2016). Here, the word intelligence refers to the ability to perceive and process data and turn it into information, and then use this information as a source for decision-making processes and behaviors carried out in this direction (Paschen et al., 2019). AI use algorithms that are human-made imitation of some laws that exist in nature for problem-solving (Zhang & Dahu, 2019). The problem-solving capacity of AI technologies makes them an important option in decision-making processes, and it is predicted that AI and other smart technologies will be the main actors in transition to automation (Jarrahi, 2018). AI, which is an interdisciplinary subject, has relations with different disciplines such as philosophy, mathematics, and statistics (Zhang & Dahu, 2019).

In 1943, McCulloch and Pitts put forward a theory based on Boolean functions and Alan Turing's Turing Machines for understanding the mental processes of neural mechanisms through logic and mathematics (Piccinini, 2004). In 1950 English mathematician Alan Turing's article entitled "Computing Machinery and Intelligence" is considered the first sign of the concept of AI (Smith et al., 2006). Pinar Saygin et al. (2019) underlined that Turing's idea has been both developed and criticized since the 1950s. The authors said that one end considers this

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approach the beginning of AI, while the other qualifies the Turing Test as useless or even harmful. Nevertheless, it is possible to say that Imitation Game or Turing Test is the starting point of almost every study on AI today (Warwick & Shah, 2016). The work by Turing is based on the "Imitation Game" and the question "Can machines think?" (Turing, 1950). Herewith, after the advent of the computer in the 1940s, it was understood that besides simple operations, these machines could do much more complex and intellectual tasks that required human intelligence (Wang, 2019). As a matter of fact, in the mid-1950s John McCarthy, one of the inventors of the concept, explained artificial intelligence as the operation of machines as if they had human intelligence (Ertel, 2018) and coined the term AI in a conference dated 1956 (Smith et al., 2006). This conference organized by John McCarthy and his colleagues at Dartmouth College formed the intellectual basis of AI (Hamet & Tremblay, 2017).

When we look at the short chronological history of AI, it is possible to say that Turing's 1950 article was a critical moment for AI, as we mentioned earlier. Drawing attention to this situation, Buchanan (2005) stated that the first book on the subject was "Computers and Thought" published by Julian Feldman in 1963, knowledge-based systems came into play and institutions began to support AI in the 1960s and 1970s, one of the first conferences on the subject was held by Donald Michie in Edinburgh in 1965. Haenlein and Kaplan (2019), on the other hand, underlined that Isaac Asimov, who wrote a book developed by engineers in a similar period to Turing but in geography 3000 miles away from him, should also take place in this history by influencing many researchers on robotics, AI and computer sciences. Zhang et al. (2023) stated that the symbolism paradigm (first generation) was dominant until the end of the 1980s, and the connectionism paradigm (second generation) was dominant in the 1990s in AI research. The authors stated that the third generation combines the knowledge-based approach of the first generation with the data-driven approach of the second. Based on a bibliometric analysis of AI research between 1990 and 2019, De la Vega et al. (2023, p. 1724) stated that research in this period focused on "machine learning, deep learning, robotics, natural language processing". Kaplan and Haenlein (2019) identified the first-period AI ("artificial narrow intelligence") with systems capable of performing specific tasks assigned to it, the second-period AI (artificial general intelligence) systems with the ability to solve problems it had not encountered before, and third-period AI (artificial super intelligence) as systems that have self-consciousness that are able to make people unneeded. Marsden (2017) has presented a detailed timeline showing AI robots starting with the Turing Test in 1950 and evolving with the support of researchers and various global companies (see Marsden, 2017). In addition, there are others who accept the beginning of AI as the emergence of the word robot and state that this word was first mentioned in a 1921 book by an author named Karel Capek (Hamet & Tremblay, 2017).

Metaxiotis and Samouilidis (2000) discussed expert systems, which can be considered as a sub-branch of AI in the field of medicine. In this study, the authors pointed out that although expert systems may be the subject of wrong use and applications from time to time, they will offer important opportunities in terms of "decision support" and "decision making". In his study dealing with the use of

decision support and exper systems in the fields of management and administration, Edwards (1992) drew attention to the fact that the first approach was based on information systems and operational research, while the second one was based on artificial intelligence.

AI language is used in decision support systems due to its ability to imitate human language, wide application area, flexibility, and speed (Rowe & Roberts, 1998). Knowledge management has become a tool used by businesses to provide profitability, productivity, and competitive advantage in areas such as customer relationship management, product and value proposition development since the 90s (Tsui et al., 2000). Noting that the increase in the use of artificial intelligence in businesses provides the opportunity to manage large-scale data in real time, Perez-Vega et al. (2021) emphasized the importance of theories explaining human behavior in the further development of theory for this area. Machine learning systems powered by big data makes possible unmanded decision (OECD, 2021).

More concretely, we can see the use of artificial intelligence in different area of our lives (Analytixlabs 2020). Marketing, social media, video games, travel, agriculture, business operations, healthcare, energy, environment, transportation, education are examples of these fields (Castro & New, 2016; Analytixlabs 2020). Although AI is a concept that emerged in the 1950s, it was included in the business environment and daily conversations approximately 50 years after this date (Haenlein & Kaplan, 2019). Stating that AI technologies have spread to social and behavioral sciences apart from computer sciences thanks to big data, Robila and Robila (2022) mentioned that "random forests, neural networks and elastic net" are the most frequently applied methods in these disciplines. The study of AI by social scientists in the fields of philosophy, psychology, cognitive science and human-computer intelligence revealed important results and constitutes a promising field of research (Miller, 2019). Wirth (2018) stated that AI is the most important game changer of today, and this can be understood in daily life from conferences, startups and large companies that invest in this field. Also, it should not be forgotten thatAI systems require various control mechanisms (such as rules, laws, constant monitoring) to be kept under control so that they can both complete their work without errors and not get out of control and become harmful (Kaplan & Haenlein, 2019).

In the next part of our study, we examine the literature review of the artificial intelligence focused on the library use.

## Literature Review

In the literature, we first focused on Libraries and their role in society. Libraries are institutions that have ideally set the mission of "All information for all people at all time" for many years (Li et al. 2019) and have been at the key point of sustainable development due to their mission of disseminating information (Msauki 2021). Digital transformation, on the other hand, requires organizations to constantly update their business models to remain competitive, such agility makes it easier to control unexpected situations such as COVID-19 (Okunlaya et al. 2022). Fourth Industrial Revolution brought many transformations

on knowledge society and these changesets put disruptive technologies such as artificial intelligence, automation, and mobile applications on the agenda of libraries (Msauki 2021). Being a pioneer in the use of technologies such as AI encourages the diffusion of new technologies, and this movement is in line with the mission of public libraries (Finley 2019).

In the context of Digital transformation in libraries, it exists many scientific researches. In the past, technical transactions such as questioning or borrowing books in libraries were carried out over the phone and fax, through time computer and internet technologies allowed the automation and digitalization of libraries (Ali et al. 2021). With the development of Web 2.0 technologies, libraries have also started to integrate the mobile leg of technological developments into their applications under the roof of library 2.0, and this transformation has followed a development process parallel to information and internet technologies (Li et al. 2019). Library 4.0, which is an extension of Industry 4.0, improves the relationship of libraries with their stakeholders by providing convenience and speed advantage, thus expanding the local status of libraries and their mission of presenting information (Msauki 2021). "Technological environment changes; the extensive and rapid growth of data; and the increase in and diversification of user needs" (Cao et al. 2018, p. 811) have created an environment full of opportunities and threats for libraries and led to the emergence of "smart libraries" (Cao et al. 2018). Li et al. (2019) stated that the digital library concept can be considered as an extension of Dowlin's "electronic library" concept coined in 1984 meaning the assistance by electronic technology in the management of information resources.

"Smart", "intelligent", "participatory" libraries are studied by many researchers. The concept of "smart libraries" was conceptualized by Aittola, Ryhanen, and Ojala in 2003 (from Aittola et al. 2003 cited by Zimmerman and Chang 2018). Smart libraries aim to improve, ameliorate, and facilitate the services they offer to users by making use of information and communication technologies (Gul and Bano 2019). Smart libraries are expected to be user-oriented and easily adapt to the changing expectations, requests and needs of users (Cao et al. 2018). Gul and Bano (2019) in their literature study on smart libraries, stated that libraries can use technologies emerging with developments in information and communication technologies such as "internet of things, RFID technologies; cloud computing, artificial intelligence, data mining, sentiment mining, augmented reality and other digital technologies like library robots and ambient intelligence, blockchain technology" (p. 778) to improve the service they offer to different stakeholders.

Cox et al. (2018) drew attention to the fact that "intelligent libraries", which is an output of the application of AI in libraries, will improve various subjects such as research, publishing, and education. The authors cited ethical concerns, reluctance to invest in these issues, and data quality as the barriers to progress in this area. The concept of "Participatory library" is another concept related to these issues conceptualized by Lankes et al. in 2007 (Yao et al. 2015). Lankes et al. (2007) defined the "participatory library" as a system for communicating with different stakeholders (users, other libraries...) by making use of web 2.0

technology's opportunities as an alternative approach to traditional and rigid systems.

University libraries use also artificial intelligence. As universities also contribute to sustainability as they are the epicenter of science, it is possible to say that academic libraries also have an important place in this process (Huang 2022). The use of AI in libraries, due to its disruptive nature, is an issue that can provide significant returns to this field if it is managed correctly (Massis 2018). While academic libraries are developing their services, they have to manage many challenging tasks such as managing printed and electronic resources, providing services suitable for changing needs, and integrating the developments in computer technology and AI into systems (Duncan 2022). Allison (2012) in a pilot study based on a system that answers students' questions with a chatbot over an AI-based system in the university library, stated that as the data increases, the quality of the chatbot's answers increases, but the main challenge remains as enabling users to reuse the chatbot. The author drew attention to the importance of integrating applications such as AI into existing systems of libraries in order to attract the attention of today's students who open their eyes to a digital world.

Artificial intelligence as a discipline was presented by McCarthy et al. in 1955 as a Dartmouth summer research project (McCarthy et al. 2006). Artificial intelligence, which is used in many sectors, refers to "machines (that) can exhibit judgment or make decisions that are consistent with human judgment and decision-making" (Wheeler and Buckley 2021). As well as the traded sectors (e.g., Alhashmi 2020, Lyu and Liu 2021, Sharma et al. 2022) artificial intelligence is a topic that is referred to in higher education (Becker et al. 2017). Automation and machine learning, which we encounter in many different industries, are also concepts related to artificial intelligence (Wheeler and Buckley 2021). Automation is the ability to carry out works based on human or, in some cases, animal power, without the need for these elements while machine learning refers to machines mimicking people's judgment and decision-making process (Wheeler and Buckley 2021).

The use of AI in libraries requires significant investment in infrastructure, funding, and training; for this reason, it can be said that large libraries such as academic libraries have started to adopt the use of AI, although not as fast as large-scale companies (Harisanty et al. 2022). Li et al. (2019), on the other hand, stated that a significant amount of software and hardware investment still needs to be made to adapt the developments in information and internet technologies to libraries. In terms of libraries, artificial intelligence can be used both to improve the services offered to the users and to facilitate background work (Bates 1999). An example of this background technical work is "collection development, acquisition of library material, classification of library material and cataloging, library automation systems" (Ali et al. 2021, p. 12). In terms of services offered to users, AI technologies (via chatbots) can perform operations such as notifying libraries when a new book is available or suggesting suitable books on the subjects sought (Oyelude 2021). Universities can improve their education and research processes and improve learning services by making use of AI (Okunlaya et al. 2022).

Asemi et al. (2021), in their literature studies focusing on the applications of artificial intelligent systems in libraries, stated that the collaboration of librarians and information technology employees will provide various benefits and conveniences to libraries. Harisanty et al. (2020) pointed out that AI can free library staff from backstage routine work, so they can devote more time to professional development and library improvement. Thanks to AI, contributing to knowledge-sharing libraries via expert systems and robots also provides an environment other than a local for community members (Msauki 2021).

Information Technology (IT) systems are used by many libraries in different fields such as online public access to catalogs, gate systems, and cataloging (Harisanty et al. 2022). Most of the AI applications currently used in libraries are standard solutions developed for the business world but in the following period, more library-oriented applications support (e.g., budget, reference, collection development...) can emerge (Duncan 2022). Dhamija and Bag (2020) in their study in which they discussed the outputs of artificial intelligence use with bibliometric analysis in organizations defined 6 clusters as "Artificial Intelligence and Optimization, Industrial Engineering/Research and Automation; Cluster, Operational Performance and Machine Learning; Cluster, Sustainable Supply Chains and Sustainable Development; Cluster, Technology Adoption and Green Supply Chain Management and Cluster, Internet of Things and Reverse Logistics". Yao et al. (2015) discussed the use of artificial intelligence in libraries through a smart-talking robot that they developed themselves in their study, in which they collected data with different stakeholders such as students and librarians through different data collection methods such as survey, in-depth interview and statistical analysis. In this study, they determined the success of such applications, which will be prominent in the future, as "self-learning, vivid logo and language, modular architecture and artificial intelligence".

We can find researches in the field of Diffusion of innovation. Cox et al. (2018) stated that artificial intelligence is most commonly used in academic libraries in the fields of research, chatbots and text and data mining, and the most important problem in this regard is user acceptance and system limitations. Lund et al. (2020) stated that libraries are enthusiastic and generally early-adopter in adopting artificial intelligence applications in their study with Rogers's theory of Diffusion of Innovation. At this point, the authors drew attention to the importance of knowledge sharing in the diffusion of innovation with reference to Rogers. Huang (2022) conducted a gap analysis study comparing the use of AI in academic libraries with librarians using and not using AI. The authors reported that their findings are parallel to Lund et al.'s (2020). Okunlaya et al. (2022) developed an Artificial Intelligence Library Services Innovative Conceptual Framework (AI-LSICF) based on the existing literature on libraries' adoption of AI applications to adapt to digital transformation. Blut et al. (2021) stated that the theory is less robust than thought in their studies on the Unified Theory of Acceptance and Use of Technology (UTAUT), which deals with technology adoption, with a meta-analysis. The authors made suggestions to make the model more inclusive by adding and testing the extensions and moderators.

We distinguished also our literature review depending various studies in different countries. According to the literature, it can be said that studies on the digital transformation process in libraries exist in both developed and developing countries. Harisanty et al. (2022) in their research with library managers, staff, and scientists to understand the perspective on the use of AI in academic libraries found that the participants viewed AI positively and were aware of its benefits. In their study of the use of AI in libraries in Pakistan Ali et al. (2021) stated that libraries use various applications such as "machine learning-based Discovery and Data Visualization Labs for security, self-check-in, checkout, citation and research analysis". In their study of the digitization process of libraries in China, Li et al. (2019) stated that the main contribution of AI to libraries can be summarized under three main headings as "resource construction, information organization and information service". Rubin et al. (2010) discussed the use of conversational agents in Canadian libraries for "educational, informational, assistive, and socially interactive" purposes. The authors stated that although these applications may seem difficult and costly to implement especially for small-scale libraries, they will become more accessible and viable with sharing-oriented library initiatives. Harisanty et al. (2022) stated that library use, preparation and awareness of AI is an understudied area, especially in developing countries.

In this stage, we focused the literature review on the impact on existing librarian profession. Automation, artificial intelligence, and machine learning technologies, which are also in the interest of non-profit organizations today, can be perceived as a threat to existing business lines (Wheeler and Buckley 2021). The threat posed using AI in the librarianship profession can be shown as one of the concerns of those working in this field (Cox et al. 2018). Wood and Evans (2018) in their research on Academics librarians' view of artificial intelligence revealed that librarians do not feel as threatened as people working in the law and medicine field and do not expect a radical change before 30 years. To avoid the risks of artificial intelligence applications in libraries, it is recommended to carry out changes carefully and systematically (Huang 2022). It will take many years for these technologies to pose a risk to existing employees, and the effect can be regulated by government regulations (Wheeler and Buckley 2021).

Bates (1999) drew attention to the necessity of looking at the applications that AI brings to libraries as a tool that reduces the drudgery of routine work rather than a threat to employees. The author stated that by using systems such as machine learning and image recognition in search processes in digital collections, they can make an additional contribution by revealing important findings that cannot obtained by human mind power. Duncan (2022) stated that by making one-to-one copies of rare materials available thanks to AI technologies, students can access these publications more easily and without waiting in line. The author stated that AI technologies will never threaten librarians and can only be a complementary and supportive tool for them. At this point, the author pointed to Liu's (2011) work on the benefits of using intelligent systems in libraries. Liu (2011) stated in this study that although there are many "architectures, frameworks and models" related to the smart systems in libraries in the literature, their application and research are understudied topics.

Although many researchers accept that the use of AI is a disruptive situation, they argue that librarians should see it as a "help", not a "replacement" (e.g., Rubin et al. 2010, Oyelude 2021). Cox et al. (2018) due to the AI's effect trabsforming librarianship-related professions these professions will also need statistical knowledge and a relatively low-paid sector will need to produce a solution in this regard. In addition, the authors stated that the use of AI in the library will not be able to radically change the traditional library in the near future, and the limited impact will also differ in the sub-branches of academic libraries. Robinson and Bawden (2017) conducted a study on the first group of students and practitioners who took the data literacy course included in the library and information science curriculum. Researchers found that the course positively regulated the participants' relationship with data in many aspects such as technological, social, and ethical.

Another aspect is the Task-technology fit model. Tu et al. (2021) discussed university students' perceptions about learning through a social media-based mobile library application, with Technology Acceptance Model and the Theory of Task-Technology fit (TTF). Through a structural equation model, the authors found that technology characteristics and task-technology fit determines consumer attitudes. Jeyaraj (2022) in their research examining the studies dealing with the Task-technology fit (TTF) model in information systems with a holistic view by meta-regression analysis revealed that the effect of TTF was affected by "type of, dependent variable and type of TTF variable". Benslimane et al. (2000) presented a model that deals with the antecedents and consequences of the use of the world wide web with the Task-Technology fit model from the buyer's perspective. Subsequently, the same authors (Benslimane et al. 2003) discussed the TTF model in business-to-business e-commerce transactions. The authors revealed scales for the application of the Task-Technology Fit Model to electronic commerce with the research they conducted on 110 corporate buyers.


**Conclusion**


This case study describes how AI (Artificial intelligence) technology is being used in various areas of university library operations. In the literature review, libraries and their role in society are firstly focused on and then digital transformation in libraries is discussed in detail. Then, the study presents the smart, intelligent and participatory libraries studied by many researchers. University libraries use also artificial intelligence. Some of the studies are shown in our paper. Due to the significant infrastructure, financial, and training investments needed to use artificial intelligence in libraries, it can be said that the big respected academic libraries have begun to adopt the technology. We also found some studies in the field of diffusion of innovation. We based our literature review on numerous studies conducted in various nations. According to the literature, studies on the process of digital transformation in libraries exist in both developed and developing nations. During our literature review, we found that one of the worries of those who work in this field can be seen to be the threat that artificial intelligence poses to the librarianship profession. Another side of this

research is the Task-technology fit model. Some authors found that technology characteristics and task-technology fit determine consumer attitudes. For a further work, we want to realize a survey that we will ask questions to librarians in order to measure their attitude toward the artificial intelligence use in the libraries.

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# The World Formula and the Theorem of Perron-Frobenius: How to Solve (Almost All) Problems of the World

*By Thomas Fehlmann[*] & Eberhard Kranich[±]*

*Transfer Functions relate the output or response $y$ of a system such as a filter circuit $A$ to the input or stimulus $x$. The response $y$ can be measured; the $x$ is the unknown. Solving the World Formula $y = Ax$ not only explains how analog images and voice can be digitally stored, but also many methods and techniques such as Big Data and Artificial Intelligence. For linear functions between vector spaces, the Eigenvector Method makes calculating a solution $x$ easy, if it exists. Numerical algorithms are available for solving. Thus, the method is suitable for teaching students who are interested in the foundations of science. However, the system $A$ must meet certain conditions to make the eigenvector method applicable. The Theorem of Perron-Frobenius defines these conditions.*

**Keywords:** *transfer functions, big data, world formula, Eigenvector method, theorem of Perron-Frobenius*

## Introduction

For decennials, *Quality Function Deployment* (QFD) has been the method of choice for uncovering hidden customer needs when creating successful products (ISO 16355 2015). The main task is to capture the *Voice of the Customer* (VoC). Many proven methods and tools exist to understand the VoC and turn it into a prioritization profile (Fehlmann 2016).

QFD uses the concept of *Six Sigma Transfer Functions* (SSTF). These functions are linear *Transfer Functions* in the form $y = Ax$, where $y$ is the vector representing qualitative or quantitative user needs, and $x$ the vector of quantitative parameters related to the technical solution characteristics. *Root Cause Analysis* and *Cause-Effect Analysis* rely on solving the world formula. Since $A$ is linear, it can be represented as a matrix (Fehlmann 2016, p. 65ff). It has many similarities to Six Sigma root cause analysis, where $y$ is the observable response and $A$ the matrix of measurements that correlate each vector dimension of $x$ with each vector dimension of $y$. For measuring these correlations in Six Sigma, the *Design of Experiments* technique (Creveling et al. 2003, p. 549) provides guidance how to get a sufficiently well-defined transfer function matrix for identifying main causes for an observed effect.

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In both QFD and Six Sigma for manufacturing, finding the right controls for the vector $x$ is the difficult part. Because of the non-decidability of first-order logic (Turing 1937), there is no automated method possible to devise the "correct" instances of $x$, not even its dimensions – otherwise we would have a general problem solver and could let computers develop new technologies and new products. See the authors' 2020 ATINER paper on the axiom of choice and decidability (Fehlmann and Kranich 2020).

The main difference between Six Sigma in manufacturing and QFD is that, in QFD, proper measurements are often not possible. Classical QFD for product design replaces measurements by team consensus; thus, measuring expert judgment rather than physical evidence.

## Literature Review

Measuring the response $y$ in QFD involves techniques to understand the VoC that often rely on social science or involve not only mathematics but also psychology such as Saaty's *Analytic Hierarchy Process* (AHP) (Saaty and Alexander 1989). Methods and techniques for the acquisition of the voice of the customer make up for the larger part of the ISO 16355 series of standards.

Finding the SSTF and assessing the right topics and dimension of $x$ requires a very creative but disciplined process. This is the essence of QFD. As for any SSTF, it is possible to validate any pair of $A$ and $x$ by applying $A$ to $x$. The result, $Ax$ is a vector with the dimensions of the original response $y$, in QFD typically the voice of the customer. Because of the measurement errors and the uncertainty of expert judgements, $y \cong Ax$ should hold but equality cannot be expected.

The vector difference between $Ax$ and $y$ is called the *Convergence Gap*. This is an indication how well $x$ together with the chosen approach described by the SSTF $A$ explain, in the sense of cause, the response $y$, or in other words, whether a product or technology based on the quantitative parameters $x$ and providing the transfer function $A$ are capable to deliver the quality requested by the user needs $y$. A small convergence gap validates the approach but does not exclude the existence of other approaches.

Let $x = \langle x_1, x_2, \ldots, x_n \rangle$ and $y = \langle y_1, y_2, \ldots, y_m \rangle$ be vectors in two respective linear vector spaces, and let the matrix $A = (a_{ij})$ be a linear transfer function, then the convergence gap is defined as the Euclidean distance between the $m$-dimensional vectors $y$ and $Ax = \langle \sum a_{i1}x_i, \sum a_{i2}x_i, \ldots, \sum a_{im}x_i \rangle$:

$$\|y - Ax\| = \sqrt{\sum_{j=1}^{m} \left( y_j - \sum_{i=1}^{n} a_{ij}x_i \right)^2} \qquad (1)$$

The convergence gap can be used to optimize the SSTF $A$, and thus the solution $x$, by using domain expertise, or by numerical optimization. The preferred method is the eigenvector method because it settles and flattens variations that originate from measurement errors or opinion blur. This was first observed by Saaty and applied for the *Analytic Hierarchy Process* (AHP) (Saaty 2003). For more details, including limitations of the AHP approach, see for instance Hontoria and Munier (2021).

For literature about QFD, consult the ISO series of standards 16355, explaining its statistical methods (ISO 16355 2015). For SSTF, consult Fehlmann (2016), and for the matrix calculations some textbook about linear algebra, e.g., Meyer (2000).

SSTF must not be confused with the *Least Square Method* (Meyer 2000, pp. 223-234), because neither observations $y$ nor the SSTF $A$ need to be continuous. The solution $x$ may jump, and in reality, it often does. When doing QFD or Six Sigma, one focuses on one, very specific observation. You do not have a data series.

However, we should mention the *Foxes Team of Volpi*. This work became famous, often referenced, and used because it extended Microsoft Excel for scientific calculations by Linear Algebra. Volpi's team created the add-on to Microsoft Excel called *Matrix.xla* (Volpi and Team 2007), the Tutorial (Volpi and Team 2004) and the Reference (Volpi and Team 2006). The authors also rely on their work to calculate SSTF by these tools in Excel.

Levie's (2012) book explains how to use Excel for scientific calculations, as a textbook for most scientific disciplines. He also maintains a web site with many useful links (Levie 2012ff). However, commercial but expensive tools such as MATLAB (Math Works, Inc. 2021) provide such functionality more intuitively but less easy to access. The open-source tool R (The R Foundation 1993) is probably better suited for educational purposes. Nevertheless, Excel is widely used for statistics and provides a simple approach to basic mathematical programming for scientists and authors.

While Levie builds on the work of Volpi's team, he also implements real numbers with higher precision, adding more stability for numerical calculations.

Such an approach is especially useful if teachers want to help students understanding the roots of the technology that dominates our century. Knowing how to use technology sometimes is not good enough; it does not allow people to distinguish fakes from reality. Therefore, they start believing unscientific claims. To educate people to freedom and self-determination they must be empowered to understand the world they are living in. A good approach to achieve this is explaining them the World Formula and thus demonstrating what it means to distinguish cause and effect.

## The Problem with the World Formula

Obviously, it is not always possible to solve the world formula. If it were, we would have solutions to all possible problems. Normally, the challenge is less

finding the solution profile **x**, but defining the transfer function **A** that describes the approach accurately.

Famous sample solutions exist; the best known probably is the analog-digital conversion used for audio and video – thus, incidentally, the foundation of the Internet as we know it today. Here, **y** is the audio wave that we can hear with our ears, while **x** is the digital representation of the audio stream as frequency ranges. The *Fast Fourier Transform* (FFT) is the algorithm that defines **A** in limited time frames (Cooley and Turkey 1965).

However, in general, the existence of solutions is not guaranteed. Even if the goal **y** is known, the transfer function **A** is not and thus no solution **x** exists.


**The Eigenvector Method**

The authors are mainly concerned with world formula solutions in the domain of *Quality Function Deployment* (QFD) and *Six Sigma* (6σ). Both use matrices and Linear Algebra for correlations and statistics. These SSTF matrices in a real vector space $\mathbb{R}^{n \times m}$, $n, m \in \mathbb{N}$, are in most cases positively definite. In QFD, such matrices are professionally guessed by expert teams; in Six Sigma, their cell values are measured by some suitable process measurement method (Fehlmann 2016).

*Correlations or Cause-Effect?*

The first misunderstanding must be to clarify that an SSTF describes a cause-effect relationship, not a statistical correlation. **x** is the cause for **y**, and **x** controls the outcome of **y** when applying the SSTF **A**. In QFD, it is a common problem that causes and effects are messed up. If **x** describes the solution, and **y** the needs of the customer that should be satisfied with the solution, then it is common when asking the customer for its needs that the customer responds with some solution idea, thus make it hard to find the best under all possible solutions **x**. Such QFD attempts are quite likely to fail.

Nevertheless, in the QFD literature quite often the statistical notion "correlation" is used when cause-effect would be correct. Correlations in statistics never tell you the direction of what causes which outcome. Correlations are useful observations for systematically exploring relationships for later determination what is the cause producing which effect. But correlations never prove anything.

On the other hand, the notion of cause-effect does not necessarily imply a quantification, how much cause is needed to produce which effect. Design for Six Sigma measurement strategies always include quantity (Creveling et al. 2003). Therefore, we prefer the notion of "transfer function" to "cause-effect", rather pointing at the need for quantification than at the quality of causality, and keep conscious about the direction from cause to effect.

*The Existence of a Solution*

If $\boldsymbol{A}$ is a SSTF between profile vectors $\boldsymbol{x}$ and $\boldsymbol{y}$, and if $\boldsymbol{y}$ is close to some eigenvector of $\boldsymbol{A}\boldsymbol{A}^\mathsf{T}$, where $\boldsymbol{A}^\mathsf{T}$ denotes the transpose of $\boldsymbol{A}$, then an approximate solution $\boldsymbol{x}$ exists such that $\boldsymbol{y} \cong \boldsymbol{A}\boldsymbol{x}$ up to the convergence gap.

Let $\boldsymbol{\tau}$ be some eigenvector of $\boldsymbol{A}\boldsymbol{A}^\mathsf{T}$ close to $\boldsymbol{y}$. There is an eigenvalue $\lambda \in \mathbb{R}$ such that $\boldsymbol{A}\boldsymbol{A}^\mathsf{T}\boldsymbol{\tau} = \lambda\boldsymbol{\tau}$. Normalizing $\boldsymbol{A}\boldsymbol{A}^\mathsf{T}$ allows setting $\lambda = 1$.

Then, by setting $\boldsymbol{x} = \boldsymbol{A}^\mathsf{T}\boldsymbol{\tau}$, $\boldsymbol{x}$ solves $\boldsymbol{\tau} = \boldsymbol{A}\boldsymbol{x}$. Thus, our world formula has a solution if the convergence gap between $\boldsymbol{y}$ and $\boldsymbol{\tau}$ is zero, respectively an approximate solution if the gap is small. In QFD and $6\sigma$, we are usually satisfied with an approximate solution, since neither our guesses nor the measurements provide exact numbers.

*Solving the World Formula*

Solving $\boldsymbol{y} = \boldsymbol{A}\boldsymbol{x}$ works best by finding a SSTF $\boldsymbol{A} \in \mathbb{R}^{n\times m}$ whose squared matrix $\boldsymbol{A}\boldsymbol{A}^\mathsf{T} \in \mathbb{R}^{n\times n}$ has an eigenvector $\boldsymbol{\tau}$ close to $\boldsymbol{y} = \langle y_1, y_2, \cdots y_n \rangle$. $\boldsymbol{A}^\mathsf{T}$ is the transpose of $\boldsymbol{A}$. The approximate solution is $\boldsymbol{x} = \boldsymbol{A}^\mathsf{T}\boldsymbol{\tau}$, since $\boldsymbol{A}\boldsymbol{x} = \boldsymbol{A}(\boldsymbol{A}^\mathsf{T}\boldsymbol{\tau}) = \boldsymbol{A}\boldsymbol{A}^\mathsf{T}\boldsymbol{\tau} = \boldsymbol{\tau}$ and $\boldsymbol{\tau} \cong \boldsymbol{y}$. Thus, solving $\boldsymbol{y} = \boldsymbol{A}\boldsymbol{x}$ involves the ability to rapidly check eigenvectors for $\boldsymbol{A}\boldsymbol{A}^\mathsf{T}$.

Since the cell values of an SSTF consists of either expert choices or measurements for the transfer of cause to effect, and since, according to ISO/IEC 16355, ratio scales are used to quantify such a transfer, we can use linear algebra to calculate the effects $\boldsymbol{y} = \boldsymbol{A}\boldsymbol{x}$. Thus, solving the world formula effectively solves problems in QFD or Six Sigma.

However, there is a caveat. An $n$-dimensional matrix $\boldsymbol{A}\boldsymbol{A}^\mathsf{T} \in \mathbb{R}^{n\times n}$ has up to $n$ eigenvectors, and we only need one. Incidentally, the theorem of *Perron-Frobenius* guarantees that for the class of positive-definite symmetric square matrices there exists a distinguished *Principal Eigenvector* that dominates all others in the following sense:

- It corresponds to the highest eigenvector;
- Its components are equally signed; i.e., there is no mix of positive and negative vector components.

Obviously, $\boldsymbol{A}\boldsymbol{A}^\mathsf{T} = \left(c_{i,k}\right)$ is symmetric for $i, k = 1, \dots, n$. When $\boldsymbol{A} = \left(a_{i,j}\right)$ for $i = 1, \dots, n, j = 1, \dots, m$, the coefficients of the associated matrix $\boldsymbol{A}\boldsymbol{A}^\mathsf{T}$ are

$$c_{i,k} = \sum_{j=1\dots m} a_{i,j}a_{j,k} = c_{k,i} \qquad (2)$$

Moreover, if $\boldsymbol{A}$ is positive definite, this holds as well for $\boldsymbol{A}\boldsymbol{A}^\mathsf{T}$. However, a few negative coefficients in $\boldsymbol{A}$ do not necessarily affect $\boldsymbol{A}\boldsymbol{A}^\mathsf{T}$; therefore, cause-effects in QFD sometimes can become negative. The theorem of Perron-Frobenius in this

context is discussed in the author's book about SSTF (Fehlmann 2016, p. 359), as well as how to proof the theorem.

**A Model for Solutions of the World Formula**

The aim of this section is to clarify that the existence of a solution for some given world formula remains unknown.

Trivial solutions always exist. Set the dimensions $m$ and $n$ equal, the SSTF is the identity transfer function and set $y = x$. However, it is not obvious what the existence of a non-trivial solution means. Given a goal profile $y$, does a SSTF $A$ and a solution profile $x$ exist, of any dimension, such that $y = Ax$ holds? For which problems can $x$ be considered a solution? How shall problems be stated?

Following the methods of mathematical logic, it is necessary to construct a non-empty model for the problems that the world formula shall possibly address. The *Graph Model* of *Combinatory Logic* (Engeler 1995) is a model of Combinatory Logic with explains how to combine topics in areas of knowledge. An excellent example for a graph model is the Neural Algebra described by Engeler (2019). The model is explained further in last years' ATINER paper of the authors in a version targeted at software testing (Fehlmann and Kranich 2022) and intuitionism (Fehlmann and Kranich 2020). From the construction of the model, it will turn out that the question whether a solution exists remains undecidable.

*The Graph Model of Combinatorial Logic Adapted to SSTF*

It is necessary to add a few properties to the graph model such that it can serve as a general model for what a SSTF can solve.

A graph model is recursively defined over a set $\mathcal{L}$ of assertions, containing a zero assertion $\emptyset$. An *Arrow Term* is recursively defined as follows:

- Every element of $\mathcal{L}$ is an arrow term.
- Let $\alpha_1, \ldots, \alpha_n, \beta$ be arrow terms, $n \geq 0$. Then
$$\{\alpha_1, \ldots, \alpha_n\} \to \beta \tag{3}$$
  is also an arrow term.

Thus, arrow terms are relations between finite subsets of arrow terms and another arrow term, emphasized as successor. Arrow terms constitute a *Combinatorial Algebra* under composition (4):

$$\mathcal{M} \bullet \mathcal{F} = \{\beta \,|\, \exists \{\alpha_1, \alpha_2, \ldots, \alpha_n\} \to \beta \ \in \mathcal{M}, \{\alpha_1, \alpha_2, \ldots, \alpha_n\} \subset \mathcal{F}\} \tag{4}$$

For extending the graph model to SSTF, called *SSTF-Model*, two more notions are needed. First, a set of *Categories* $\mathcal{C}$ must exist such that every assertion has one or more categories assigned. The categories correspond to the rows and

columns in SSTF matrices. They reflect the kind of assertion that an element of $\mathcal{L}$ is referring to. Arrow terms of the logical form (3) are often represented as *Ishikawa Diagrams* (Ishikawa 1990).

The categories of an arrow term are the union of the categories of its subterms. The categories of $\mathcal{M} \bullet \mathcal{F}$ are the categories of its elements. Denote the categories of an arrow term $\alpha$ by $\mathcal{C}(\alpha)$ and the category of a set of arrow terms $\mathcal{M}$ by $\mathcal{C}(\mathcal{M})$. A term, or a set, corresponds to more than one category.

*Arrow Terms with a Size*

To an arrow term, a *Size* can be associated. This is a scalar that reflects its weight. This can be functional size, cost, effort, or importance for customers that occur when the item described by the arrow term is realized.

For an arrow term $\alpha$, denote its size by $\|\alpha\|$; for a set of arrow terms $\mathcal{M}$, by $\|\mathcal{M}\|$.

The needed properties of a size are given in equation (5).

$$\|\emptyset\| = 0$$

$$\|\{\alpha_1, \dots, \alpha_n\} \to \beta\| \geq \sum_{i=1}^{n} \|\alpha_i\| + \|\beta\|$$

$$\text{if } \mathcal{M} = \{\alpha_1, \dots, \alpha_n\}, \text{then } \|\mathcal{M}\| = \sum_{i=1}^{n} \|\alpha_i\|$$

$$\|\mathcal{M} \bullet \mathcal{F}\| \leq \|\mathcal{M}\| + \|\mathcal{F}\|$$

(5)

Every type of arrow term size is a *Ratio Scale* (ISO 16355 2015). It cannot fall below zero, and it has no upper limit.

However, the properties (5) do not define size in full; they leave room for specificities. If the size is functional size, or test size, the base assertions in $\mathcal{L}$ most likely have size 0. In that case they just specify the program state before execution of a test, or function. If size is weight, or cost, even base assertions add size, and the size of higher-level arrow terms is effectively is not larger than the size sum of its terms.

*Construction of an SSTF-Model*

Assume a collection of finite arrow term sets $\mathcal{M} = \{\mathcal{M}_i | i = 1, \dots, n\}$ arranged as a $n \times m$ matrix, with

$$\mathcal{M}_i = \left\{ \{\alpha_{i,1,k}, \dots, \alpha_{i,m,k}\} \to \beta_{i,k} \middle| k \in \mathbb{N} \right\}$$

(6)

One can associate an SSTF $A = (a_{i,j})$ with a goal profile $y = \langle y_1, y_2, \cdots, y_n \rangle$ using the total size of the arrow terms that refer to the matrix cell $i, j$

$$a_{i,j} = \sum_{k \in \mathbb{N}} \| \alpha_{i,j,k} \| \qquad (7)$$

Thus, an approximate solution $x = \langle x_1, x_2, \cdots, x_m \rangle$ may exist for the equation $y \cong Ax$. If so, it proves the suitability of the SSTF model. The model (6) for the SSTF $A$ consists of the arrow terms $\mathcal{M}_i$ filling the row with index $i$ in the matrix. If such a model exists, the SSTF $A$ with cell values (7) might have a solution. Using the convergence gap, it is decidable whether a solution exists. It is left to the reader to argue why it remains undecidable whether such a model $\mathcal{M}$ exists, given some SSTF $A$.

*Detailed SSTF-Model*

Figure 1 might help understanding how SSTF and arrow terms relate to each other. Assume a matrix cell on the $i_0{}^{\text{th}}$ row and the $j_0{}^{\text{th}}$ column, with its neighboring cells indexed $i_0 + 1$, respectively $j_0 + 1$. These four cells are shown in
Figure 1 together with the corresponding arrow terms.

**Figure 1.** *An SSTF-Model Extract for Rows $i_0$ Respectively $i_0 + 1$*



The same category, corresponding to the $j_0{}^{\text{th}}$ and the $j_0 + 1{}^{\text{st}}$ column are shared by all terms $\alpha_{i,j_0,k}$ and $\alpha_{i,j_0+1,k}$ respectively. The size of the cells is the sum of the $\| \alpha_{i,j,k} \|$, as in equation (7).

*Improving the Transfer Function*

Sizing arrow terms allows for quality assessment of the underlying cause-effect analysis. When an SSTF has no solution, that is, the convergence gap does

not close, adding or removing arrow terms to the model $\mathcal{M}$ adds or decreases size in a cell and thus might solve $\boldsymbol{y} = \boldsymbol{Ax}$ by modifying the SSTF $\boldsymbol{A}$. Note that any such change means that additional or removed arrow terms in the model means that the transfer function is improved by adding or removing actions connected to each cell in the matrix.

## Numerical Methods

Numerical methods for solving the world formula originate from Gauss but have been deeply enriched in the past few decencies.

### *The Power Method*

If $\boldsymbol{\tau}$ is an eigenvector of a square matrix $\boldsymbol{A}$, then its corresponding eigenvalue is given by

$$\lambda = \frac{\boldsymbol{\tau}^{\mathsf{T}} \boldsymbol{A} \boldsymbol{\tau}}{\boldsymbol{\tau}^{\mathsf{T}} \boldsymbol{\tau}} \tag{8}$$

This quotient is called the *Rayleigh Quotient*. For the proof, see for instance the authors' book about transfer functions (Fehlmann 2016, p. 358).

The power iteration algorithm starts with a random vector $\boldsymbol{\tau}_0$, if possible, near to the principal eigenvector. The method is described by the recurrence relation

$$\boldsymbol{\tau}_{i+1} = \frac{\boldsymbol{A} \boldsymbol{\tau}_i}{\|\boldsymbol{A} \boldsymbol{\tau}_i\|} \tag{9}$$

At every iteration, the vector $\boldsymbol{\tau}_i$ is multiplied by the matrix $\boldsymbol{A}$ and normalized.

Hence, in cases for which the power method (9) generates a good approximation of a dominant eigenvector, the Rayleigh Quotient (8) delivers a good approximation of a dominant eigenvalue. Thus, (8) indicates whether the power iteration found the principal eigenvector, or some other.

The power iteration algorithm is robust but slow.

### *The Jacobi Iteration*

In numerical linear algebra, the Jacobi eigenvalue algorithm is an iterative method for the calculation of the eigenvalues and eigenvectors of a real symmetric matrix. This process is known as diagonalization. The original algorithm was published by Rutishauser (1966).

The Jacobi eigenvalue method repeatedly performs rotations around the off-diagonal element with the largest absolute value, called the *Pivot*, until the matrix becomes almost diagonal. Then the elements in the diagonal are approximations of

the (real) eigenvalues. For details, consult a textbook, e.g., *Numerical Recipes* (Press et al. 2007).

The Jacobi iteration is popular because of its speed and intuitiveness. The figures below show the steps needed according to this method to calculate the eigenvalues and the eigenvectors of a typical QFD matrix.

Figure 2 is a matrix originating from a real QFD that does not provide a response profile $\tau$ near to the goal profile $y$. In this case, the domain consists of investments into product characteristics $tc_1, \dots tc_6$, providing value for the user $cr_1, \dots, cr_8$. The total investment needed is represented by the solution profile below the matrix $A$. The same investment has impact on various user values.

The corresponding world formula has a model – the cause-effect relations that written as arrow terms, were used to expert estimate the QFD matrix.

**Figure 2.** *Insolvable QFD Matrix*
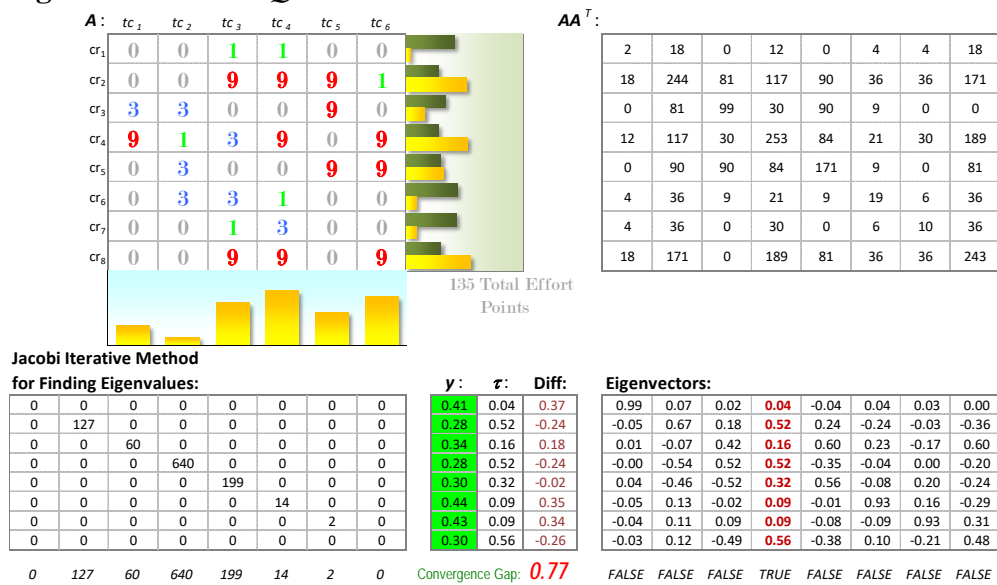


*Source:* Own work, using a QFD matrix from Wu et al. (2005).

However, at least for the domain under scrutiny, $A$ is not a solution. This is made visible by the comparison between $y$ and $Ax$ shown right from the first upper matrix, the QFD matrix in Figure 2. Below this matrix is the solution profile $x$. The authors of the original QFD matrix realized this and tried to use "Grey Theory" (Wu et al. 2005) to better analyze dynamic customer requirements. Their SSTF $A$ needs improvements, possibly additional or less columns for the product characteristics, or correct cause-effect relationships. Adapting the implementation $A$ changes the solution profile $x$ and thus $Ax$.

Since cell values in QFD matrices dynamically reflect relative importance, not static, immutable physical measurements, improving these values is an excellent way for finding better solution for the world formula. For instance, this might be used to create better products at less cost. It is therefore highly desirable

to find a way how to improve an "insolvable" QFD matrix. For more details, see the series of standards ISO 16355 (ISO 16355 2015).

*The Winding Stairs Method*

Is it possible to improve the SSTF $A$ with the existing product characteristics such that the investments are better focused on customer's needs? Applying the global sensitivity analysis *Winding Stairs Method*, see for instance Fehlmann and Kranich's (2023) respective paper, it is possible to mathematically improve the SSTF. However, such an improvement only considers the information 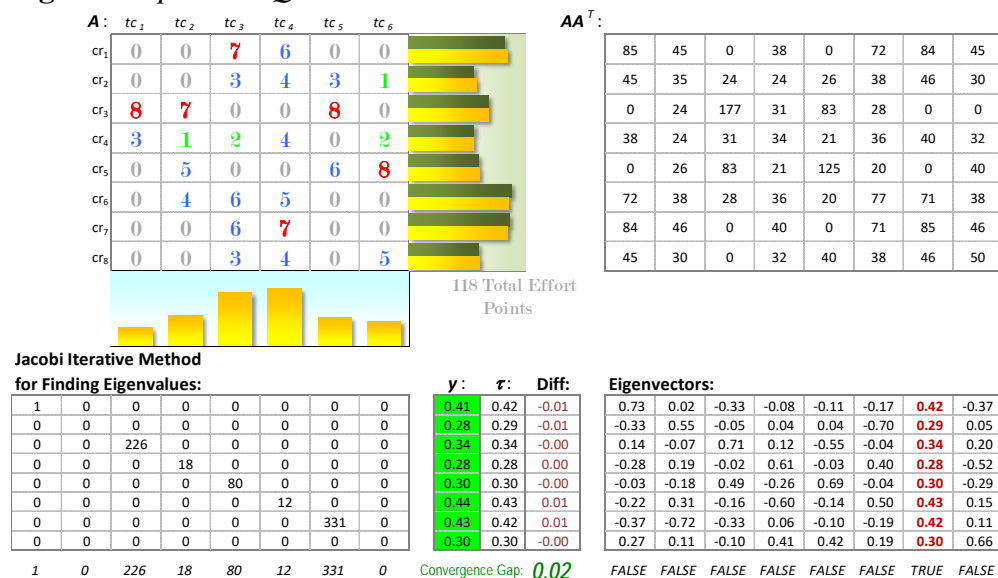that had been supplied to the original SSTF and therefore just optimizes distribution of effort, or budget, ignoring other possibilities such as adding another technical product characteristics.

Figure 3 shows the automatically improved QFD matrix.

The convergence gap closes. Thus, this QFD reflects not just measurements of some cause-effect relationships but can be used as a planning matrix, indicating how much effort, or coupling, you need in each cell to achieve a response near to the goal profile.

**Figure 3.** *Optimized QFD Matrix*

$A$:

| | $tc_1$ | $tc_2$ | $tc_3$ | $tc_4$ | $tc_5$ | $tc_6$ |
|---|---|---|---|---|---|---|
| $cr_1$ | 0 | 0 | 7 | 6 | 0 | 0 |
| $cr_2$ | 0 | 0 | 3 | 4 | 3 | 1 |
| $cr_3$ | 8 | 7 | 0 | 0 | 8 | 0 |
| $cr_4$ | 3 | 1 | 2 | 4 | 0 | 2 |
| $cr_5$ | 0 | 5 | 0 | 0 | 6 | 8 |
| $cr_6$ | 0 | 4 | 6 | 5 | 0 | 0 |
| $cr_7$ | 0 | 0 | 6 | 7 | 0 | 0 |
| $cr_8$ | 0 | 0 | 3 | 4 | 0 | 5 |

$AA^T$:

| 85 | 45 | 0 | 38 | 0 | 72 | 84 | 45 |
|---|---|---|---|---|---|---|---|
| 45 | 35 | 24 | 24 | 26 | 38 | 46 | 30 |
| 0 | 24 | 177 | 31 | 83 | 28 | 0 | 0 |
| 38 | 24 | 31 | 34 | 21 | 36 | 40 | 32 |
| 0 | 26 | 83 | 21 | 125 | 20 | 0 | 40 |
| 72 | 38 | 28 | 36 | 20 | 77 | 71 | 38 |
| 84 | 46 | 0 | 40 | 0 | 71 | 85 | 46 |
| 45 | 30 | 0 | 32 | 40 | 38 | 46 | 50 |

118 Total Effort Points

**Jacobi Iterative Method for Finding Eigenvalues:**

| | | | | | | | | $y$: | $\tau$: | Diff: | Eigenvectors: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.41 | 0.42 | -0.01 | 0.73 | 0.02 | -0.33 | -0.08 | -0.11 | -0.17 | 0.42 | -0.37 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.28 | 0.29 | -0.01 | -0.33 | 0.55 | -0.05 | 0.04 | 0.04 | -0.70 | 0.29 | 0.05 |
| 0 | 0 | 226 | 0 | 0 | 0 | 0 | 0 | 0.34 | 0.34 | -0.00 | 0.14 | -0.07 | 0.71 | 0.12 | -0.55 | -0.04 | 0.34 | 0.20 |
| 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0.28 | 0.28 | 0.00 | -0.28 | 0.19 | -0.02 | 0.61 | -0.03 | 0.40 | 0.28 | -0.52 |
| 0 | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 0.30 | 0.30 | -0.00 | -0.03 | -0.18 | 0.49 | -0.26 | 0.69 | -0.04 | 0.30 | -0.29 |
| 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0.44 | 0.43 | 0.01 | -0.22 | 0.31 | -0.16 | -0.60 | -0.14 | 0.50 | 0.43 | 0.15 |
| 0 | 0 | 0 | 0 | 0 | 0 | 331 | 0 | 0.43 | 0.42 | 0.01 | -0.37 | -0.72 | -0.33 | 0.06 | -0.10 | -0.19 | 0.42 | 0.11 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.30 | 0.30 | -0.00 | 0.27 | 0.11 | -0.10 | 0.41 | 0.42 | 0.19 | 0.30 | 0.66 |
| 1 | 0 | 226 | 18 | 80 | 12 | 331 | 0 | Convergence Gap: 0.02 | | | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | TRUE | FALSE |

*Source:* Own work, based on an improved QFD matrix from Figure 2.

The *Total Effort Points* – the total sum of all the cause-effect relationships, an indicator for total cost of all the product improvement measures – even had slightly decreased compared to Figure 2. On the other hand, the need to invest in $tc_2$ has significantly increased and decreased somewhat for $tc_6$. This is a finding by machine intelligence, whilst there might be other constraints not reflected in the optimization method and thus not known to the "intelligent" machine that should be considered before deciding about investments.

Various other only marginally less optimal solutions for the SSTF exist that also provide value for the user. A small convergence gap is also possible when improving different product characteristics. Solutions to the world formula are something that make fun to play with and are often quite insightful.

*An Afterthought on the Windings Stairs Method*

Without going into the details of the *Windings Stairs* (WS) method, shown elsewhere (Fehlmann and Kranich 2023), the elegance of this numerical method is worth an afterthought. This method uses a principle often used in Artificial Intelligence (AI) and Big Data. Thus, it is capable of effectively surprising human users because it can do this faster than humans. However, it is not using any kind of creativity that otherwise is known for its uttermost importance in product design and improvement.

For a QFD matrix, there exists an undirected graph connecting the technical solution constraints with the goal topics, the edges represents the weighting of the connection. Note that the number of nodes is the maximum of both dimensions of the matrix. Cluster algorithms, well-known from AI, simulate the flow through the graph with the help of so-called random walks. A cluster algorithm over the permuted matrix yields at least one cluster – that would be the trivial case.

For minimizing the convergence gap, one strategy is to use the differences $y - \tau_y$ and reorder the absolute differences in descending order.

These are the nodes that may have a major impact on the reduction of the convergence gap. The original QFD matrix must of course be permuted, row by row.

The cluster algorithm provides an ordering of the nodes based on impact, as shown in Figure 4. This order can be used as strategy for WS, because at each iteration the nodes must be traversed once. Processing is cyclic.

**Figure 4.** *The Winding Stairs' Way of Solving the World Formula*
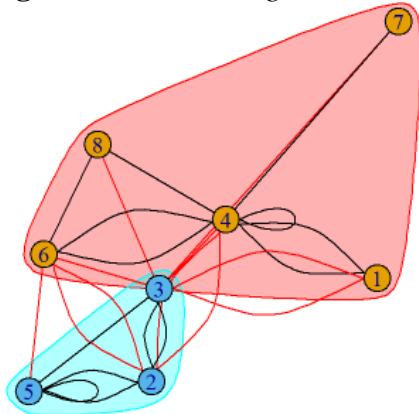


*Source: Own work, based on R* (The R Foundation 1993).

The order of the promising nodes, i.e., the rows and associated entries of the QFD matrix, visited by the Winding Stairs' vertex access sequence in Figure 4 is 4-6-1-7-8-3-5-2; the first five being in the upper (red) area where the impact on the

convergence gap supposedly is highest. Since the values of the elements of the QFD matrix are limited downward and upward, the convergence gap can be made smaller than any predefined limit.

## Conclusions

Knowing how to solve the world formula is both important and useful. It involves not only linear algebra but numerical methods as well. Thanks to numerical methods, the world formula has become more democratic in the sense that today almost everyone has access to the necessary computing power. Everybody can solve problems and find solutions once they have access to the relevant facts.

Indeed, even pandemics would be easier to defeat when providing information based on facts and measurements instead of imposing "rules" with questionable effects. People who understand how to solve the world formula are likely to less believe in allegations of the mighty or the majority. For education to democracy and self-determination, addressing the world formula and its solutions is paramount.

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**Appendix**

*Using Matrix.xla from Volpi*

A function that returns multiple values is called "array function". The *Matrix.xla* tool contains a wide range of array functions, described in Volpi and Team (2006). The Tutorial (Volpi and Team 2004) helps users learning how to use them.

The main principle is that calculations with vectors and matrices can be made by specifying using Excel ranges as variables and arguments. Since Excel does not allow to have compound data stored in a single cell, but represent matrices by rectangular tables, a trick is used that was introduced to Excel in its very early versions. In order to calculate a matrix or vector at once, one can select the whole area where the result shall be placed and enter the formula into the selection, using the "magic" key sequence *Ctrl+Shift+Enter*.

The formula is then shown within curly brackets. Entering curly brackets manually is useless; just use the magic key sequence. For instance, in Figure 2 and Figure 3, to calculate $AA^\mathsf{T}$, enter the Excel formula

$$\{= \text{MMULT}(TransferFunction; \text{TRANSPOSE}(TransferFunction))\} \tag{10}$$

where $TransferFunction$ is an Excel name referring to the Excel range containing $A$. The eigenvalues are the calculated by

$$\{= \text{MatEigenvalue\_Jacobi}(AAT)\} \tag{11}$$

where $AAT$ is the Excel name for the range containing $AA^\mathsf{T}$. By virtu of the Jacobi method, the eigenvalues are in the diagonals of the resulting square matrix. Finally, the eigenvectors are written in another square range by

$$\{= \text{MatEigenvector\_Jacobi}(AAT)\} \tag{12}$$

and he principal eigenvector is easily detectable by searching for the largest eigenvalue. MatEigenvector_pow() and MatEigenvalues_pow(), two array functions applying the Power Method, are also available.

*Using the R Package*

R has no table interface such as Excel. Similar to other programming languages, one has first to install the respective library before using it. In R, it is call *Package*. However, the eigenvector calculation does not require any additional package.
In the R GUI, an $n \times m$ matrix is entered by

$$A \leftarrow \text{matrix}(\text{data} = c(a_{1,1}, a_{1,2}, \ldots, a_{n,m}), \tag{13}$$

$$\mathrm{nrow} = n, \mathrm{ncol} = m, \mathrm{byrow} = \mathrm{TRUE})$$

without line breaks. Then,

$$\mathrm{eigenPairs} \leftarrow \mathrm{eigen}(\mathrm{tcrossprod}(A), \mathrm{symmetric} = TRUE) \tag{14}$$

simply fills into eigenPairs the eigen() decomposition $values and $vectors.

Note that eigenPairs can become all negative and might need a sign change.

The Windings Stairs' Way is explained in full detail by Fehlmann and Kranich (2023). The graphics in Figure 4 is constructed using the package igraph.

The following steps are needed:

- Create an igraph object, say actual_graph
- For this object create an adjacency table
- Apply the function cluster_walktrap originating from igraph
- For vector graphic output, use svg(cluster_walktrap(actual_graph)) or use any other appropriate R output function, see Kabacoff (2015).

That's all!

# Progress Reimagined: A Generation Z Perspective on Belfast in Relation to the UNSDGs

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*This research explores a contemporary outsider view of Belfast, through the eyes of Generation Z visiting college students, in relation to how three United Nations Sustainable Development Goals (UNSDGs) are carried out (Good Health and Well-Being, Climate Action, and Peace, Justice, and Strong Institutions). To learn through firsthand accounts, the researchers utilized ethnographic and phenomenological methods, as interacting with locals to gather community inputs, surveying different groups in the city, recording quotes said by citizens and displayed at billboards, and applying personal sensory experiences. It was found that a political deadlock plays a major role in the lack of steadiness. The research shows that Northern Ireland has progressed in many ways but also that it is still being limited by inefficient governmental practices. The rather brief time spent in Belfast barely allowed the researchers to feel and sense its atmosphere but deterred them from making recommendations.*

**Keywords:** *Gen Z, Belfast, UNSDG, phenomenological, ethnographic*

## Introduction

History follows patterns of frictions and growth. Conflicts, wars, recessions, and crises, at some point unravel paving the way for a new era of peace and progress. Generally, there is not a clear cut between them, instead a period of uncertainty gives way to the emergence of a new paradigm.

The city of Belfast has trailed this model from the lows of the Great Famine that devastated Ireland in the nineteenth century, to become a well-known industrial and merchant town with a booming economy based in linen production and ship building, before facing the economic collapse of 1929 and having been bombed during the second world war. And then, from the sixties to the nineties, Northern Ireland (NI) underwent a civil war-like period (roadblocks, street fighting, bombings, and killings) known as "the troubles," catalyzed by the acutely polarized standpoints of Protestants/Loyalists and Catholics/Nationalists, as the

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former wanted NI to remain part of the United Kingdom (home rule), while the latter sought NI to join the Republic of Ireland.

The Good Friday Agreement (GFA) of 1998, which brought an end to "the troubles," established a power-sharing government in NI, but tensions and mistrust between the two main communities remained. To this day, people are still plagued by generational trauma seeped into their culture. This trauma has led to the ineffectiveness of NI's administration. Governmental shutdowns, political disagreements, and lack of action are often at the core of the NI Assembly, limiting its ability to pass legislation. In the past year, there was a total government shutdown due to a dispute over policy. Almost thirty years since the GFA, Belfast's people are striving for understanding and hoping to find a path for sustainable growth.

As, with the aim to transform our world, the United Nations' Sustainable Development Goals (SDGs) are a call to action to end poverty and inequality, protect the planet, and ensure that all people enjoy health, justice, and prosperity; Belfast's culture constitutes an amazing case study on how to move forward from a period of conflict.

This academic journal started as a research endeavor in public history. It entails the workings of eight honor students and a professor from Belmont University who were visiting Queen's University on a semester-long trip abroad in the fall of 2022, seeking to appreciate Belfast's ethos from an outsider perspective.

In the belief that research is always needed for ingenuity, this study resulted a worthwhile effort due to the imperative to understand if/how Belfast is progressing towards development and progress. The goal of this research was to provide an unbiased, contemporary, reading on how local people face the SDGs. Although, due to the small cohort size, it was decided to just focus on three SDGs: Good Health and Wellbeing; Peace, Justice, and Strong Institutions; and Climate Action.

The class was foreign to the struggles of NI and therefore held no bias. Although lacking contextual knowledge could be seen as an obstacle, it provided an amazing opportunity to objectively study the culture with no prejudices. Since the paper embodied the "Generation Z" perspective, there are nuances to the norm of most academics' scholarly writings. Based almost entirely on primary sources, through formal interviews, casual conversations, firsthand responses, personal accounts, news articles, billboards, graffities, and song's lyrics, students collected information and crafted three research questions and one hypothesis.

> R.Q. 1: "Is the stagnant state of NI's government hindering efforts to reform the healthcare system?"
> R.Q. 2: "What effect does the lack of strong institutions in the NI government have on its current peace process and justice system?"
> R.Q. 3: "In what ways is NI behind the rest of the UK in its climate action plan, and why is that?"
> HYPOTHESIS: "The lack of a stable government, caused by lasting sectarian division, is upholding these problems, and constraining people from cooperation."

**Research Approach and Methodology**

The idea of linking the present perspectives and circumstances of Belfast with some SDGs, getting most of the material as firsthand ethnographic and phenomenological information from local sources, challenged the authors. But still more challenging was to induce the students to teaming for work on a flexible and unstructured project with novel format and methods. Till then, most of their assignments in different college classes were individual and clearly specified by a strict rubric with defined goals and expectations, and they were attached to the idea of working alone for a grade.

Attempting to understand without judging, through an unbiased and honest lens, their strategy was encouraged by Smyth (2017) argument that, *In Ireland, all history is applied history.* He stated that, on one hand, due to Ireland's fresh turbulent period: revisionism can be objected as positivistic, historians as subjective and constrained by cultural assumptions, and narrative as plagued by elisions, abridgements, and fictive elements. While on the other hand, post-revisionism unlocked opportunities, particularly for novice researchers, of non-authorized approaches.

Upon landing in Belfast, the students had no prior knowledge of the city, and thus no prejudices that could cloud their judgement. With nothing in hand, and with everything in front of them looking blurry, they gathered information through diverse sources, including visits to museums, conversations with local peers, and first-hand accounts from citizens. Many residents were eager to speak about their experiences, including some secondary or passed on generationally. These accounts offered a personalized voice into the research. In this way, the students nurtured an understanding of the NI's culture by sharing observations and debating their findings with each other.

A first assignment consisted in preparing a PowerPoint presentation about the history of Belfast comprising: early history, merchant and industrial town, partition 1912-1920, conflict 1929-1922, the Great Depression, Second World War, the Troubles, and recent history. The approach for this assignment was to work as in a matrix. First (vertically), students prepared and presented their own individual PowerPoints. Second (horizontally), each student was designated as editor for only one of the topics, with the responsibility to put together a consolidated version of the eight individually presented slides on that matter. Then, an open discussion took place, allowing everyone to debate and to suggest adjustments, until a final group version of the presentation was agreed.

With this basic background about the city, the next challenge was to select which SDGs to pick. Each student was asked to choose two SDGs. When presented to the team, some SDGs were chosen by more than one student, permitting team work on them. That preliminary selection included SDG 3 (Good Health and Well-Being), SDG 4 (Quality Education), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 13 (Climate Action), and SDG 16 (Peace, Justice, and Strong Institutions).

Every class, students were requested to bring at least two pieces of information about a link between their SDGs and the city of Belfast. Those came

in the form of comments heard in the school or on the street, song lyrics, statistics, news, graffiti, billboards, and all sort of ethnographic and phenomenological sources, including sensory experiences, personal feelings, atmosphere, visual images, and fears and hopes perceived in the society. Then, discussions took place trying to make sense of them, finding context within a specific goal, and searching for ways to contrast or verify them. Finally, everything was compiled for permanent ongoing review.

Simultaneously, with the aim of expanding students' vocabulary, and to help them navigate this nonlinear and malleable experience, each one was provided with a set of three types of prompted cards to kickstart creativity (Smith Whitehouse 2021), from where they elaborated about their topics by combination, juxtaposition, and discernment. Connecting the essential ingredients for creative work (action, perspective, and intention) in a way that they might not have done before, considering new thresholds to cross, and positioning themselves on stimulating new pathways. This combinatory play was aimed to link dissimilar dots while taking imaginative leaps forward by being open, determined, and fearless. Each of those cards focused on a specific word that the students needed to include in their writing. For example, if the word was "persevere" they should have written something along the lines as: "NI has had to learn to persevere through its long history of sectarian violence to move forward in the peace process."

Along the way the role of the professor was limited to guide the research process, recording findings, moderate discussions, time management, methodology, and vocabulary adjustment. What fell completely off limit for him was to do his own research or to bring to the table any kind of information. That was reserved exclusively to the students.

By the second half of that semester abroad, it was self-evident that the handling of six SDGs resulted beyond their possibilities, as research questions and hypotheses overwhelmed the team. Then, they decided to shorten the scope to SDG 3 (Good Health and Well-Being), SDG 13 (Climate Action), and SDG 16 (Peace, Justice, and Strong Institutions).

At the end of the semester all the available information was compiled, the research questions and the hypothesis were enunciated, and the bibliography was finished. Afterward, during the following semester, they addressed the managing of that information as well as the formatting and writing of the paper. During this process, students individually wrote each section of the paper with the professor acting as editor after a round of team debate.

This study attempted to ascribe to the Pragmatic paradigm. Nevertheless, traces of the Interpretive/Constructivist and of the Transformative paradigms can easily be spotted, as the theoretical schools embraced were ethnomethodology and phenomenology.

The approaches incorporated were Mixed Methods and Community-based Participatory. The practices were surveys, interviews, and unobtrusive methods. Surveys allowed researchers to obtain unfiltered intimate responses from primary sources. Interviews permitted information to be collected in an easy manner, showing the reality through the eyes of local individuals, instead of relying

exclusively in journals and other academic sources. However, unobtrusive methods such as document analysis and historical comparative were also explored. By means of the community-based participatory approach students were able to observe social actions.

**Findings**

Related to R.Q. 1: "Is the stagnant state of NI's government hindering efforts to reform the healthcare system?"
On February 23rd, Daily Chatter (2023) published:

Tens of thousands of nurses, ambulance drivers, and other workers in the UK's public National Health Service (NHS) recently staged the biggest strike in the service's 75-year-old history. "The government needs to listen and discuss pay rather than just saying the NHS doesn't have money," nurse Ethna Vaughan told Reuters during a protest in London at St. Thomas' Hospital. "We cannot survive with what we're being paid."

Adding to this nationwide concern, Healthcare in NI is seen by the community as a system of everlasting dereliction. Underfunded, insufficient to meet patient demands, with dubious quality and reliability, and ranking significantly below the rest of the United Kingdom.

As medical needs continued to grow, healthcare services could not cope with the demand. Since 2014, the number of general practitioners has declined by 8% while the number of patients has grown by almost 14% (Department of Health 2021a). Long waiting lists generate delays that lead to worsening conditions for the untreated patients (O'Neill 2022).

People from diverse walks of life who had firsthand experiences with the system expressed "Our hospitals are a nightmare" (Chatten 2022) and "The current system is broken" (Fombu 2022). The former elaborated on personal frustration trying to get an appointment for surgery that was rescheduled more than once due to doctors and nurses quitting. A Queen's University student told a similar story, mentioning that she had a dislocated knee, and that the day when her surgery was scheduled, she received a phone call from her doctor explaining that they needed to push her surgery back 6 weeks. Others shared accounts of being deprived of treatment or ignored when attention was needed. They also mentioned mediocre care and constant strikes of doctors and nurses, claiming to be underpaid and overworked. It seemed like no one in Belfast was near satisfied with their healthcare system.

Patients with severe disabilities, including mental health, are much more likely to have their needs unmet and to face significant barriers including transportation and accessibility. NI has commanding levels of mental health illnesses, when compared to any other region in the UK. Betts and Thompson (2017) pointed out a major issue, "Despite self-harm being a known precursor to suicide, those who presented to emergency departments in NI with self-cutting alone were the most likely to be discharged after treatment or leave without being

seen." Those with critical needs cannot get immediate access to the help that they need and even after waiting multiple months help is not a guarantee. Target goals for improvement to mental health services are often missed in N.I (Department of Health 2021b).

Related to R.Q. 2: "What effect does the lack of strong institutions in the NI government have on its current peace process and justice system?"

The GFA was signed in 1998 to promote peace and stability in NI and to create a power-sharing executive committee. From the outset, there was significant opposition from the Unionist party, with around 45% of the Protestant community voting against the agreement, in the belief that Nationalists benefited more from its provisions. Despite this opposition, the GFA was signed, and Sinn Fein and the Democratic Unionist Party (DUP) became the two main ruling parties in the state. John Hume (The Irish News 2023) stated, "In NI, we should have institutions that respected the differences of the people and that gave no victory to either side." In May 2007, after Sinn Fein agreed to support the NI police force, an Executive was established, and Peter Robinson of the Democratic Unionist Party became the First Minister of NI.

However, the ultimate inability of Sinn Fein and the DUP to work together has led to a legacy of instability in NI, resulting in a deeply divided government unable to address major political issues such as the cost-of-living crisis, education, crime, and that face difficulties in maintaining the goals of the GFA. Government pettiness and political deadlock continue to be a recurrent challenge. Social Democratic and Labor Party (SDLP) leader Colum Eastwood (The Irish Times 2022) was quoted saying that "...after 15 years of crisis and failure and walking in and walking out of government, the two parties that are at the very top have failed this community."

Although Lewis (2016) mentioned that 24 years after the GFA, "NI continues to be among the most divided societies in Europe," the sentiments on the streets of Belfast, among Gen Zs in the fall of 2022, displayed progress towards a durable peace. Perhaps, it could be attributed: Firstly, to the EU orchestrated Peace IV initiative for NI and the border counties of Ireland (Belfast City Council 2023). This initiative has four core objectives: shared education initiatives, support for marginalized children and young people, provision of new shared spaces and services, and projects that will build positive relations with people from different communities and backgrounds. And secondly, to the influence of many popular songs, embedded in the minds of the younger generations, that allude to the old sectarian fight while working on the idea that peace cannot be achieved through violence. Calling for peace and tolerance instead. Among them, "The Island," by Brady (1985) states, "up here we sacrifice our children to feed the worn-out dreams of yesterday" and "still trying to reach the future through the past, still trying to carve tomorrow from a tombstone." Also, "Zombie" by The Cranberries (1994), said "But you see, it's not me, it's not my family, It's the same old theme, since 1916, In your head, in your head, they're still fighting, with their tanks and their bombs and their bombs and their guns, in your head, in your head, they are dying."

Related to R.Q. 3: "In what ways is NI behind the rest of the UK in its climate action plan, and why is that?"

Climate change epitomizes an existential crisis to the world, and NI is certainly not immune to its effects. In the past, climate action was not as pressing an issue as it currently is since the world was not in such a distressing state. Even when it has become an indisputable subject of world's attention, NI lacks legislation to properly address it. Meanwhile the Belfast City Council has drafted the "Belfast Resilience Assessment," which includes several problems that the city intends to improve upon. One of them being climate change (Belfast Council City 2020). The goals of the city are aligned with the UN Sustainable Development Goals.

As stated by the UK Climate Change Risk Assessment (2022), there will be continued flooding and coastal change that will put communities, businesses, and infrastructure in NI at risk due to a lack of new, stronger, or different government policies able to reduce long-term vulnerability to climate change. Being a harbor city, Belfast will potentially face it worse than other areas.

The Intergovernmental Panel on Climate Change (2022) demanded immediate action in the next twelve years to cap global warming effects at 1.5 degrees Celsius. Belfast intends to move forward with a greener outlook with programs that are set out to make progress towards the city's overarching goal of "transition to an inclusive, net-zero emissions economy in a generation" (Belfast City Council 2020).

A billboard outside of Queen's University portrays "We only have 8 years for the whole world to urgently and significantly reduce greenhouse gas emissions before we will see irreversible changes to the climate of the Earth."

The farming sector in NI still struggles in areas such as water quality, emissions, and biodiversity. Some pressing issues include grass utilization that is significantly below optimal levels, less than 10% of farmland in NI has an up-to-date soil analysis, 64% of the soil does not have optimum PH levels, and the fact that 63% of NI water bodies are not achieving the "good or better" status required by the European Union directive establishing a framework for community action in the field of water policy (EC Directive 2000). In 2020 agriculture was responsible for 37% of all greenhouse gas emissions.

As "too many farmers associate the environment with regulation and penalties leading to a culture of fear" (Gilliland 2016), changes in how government regulates and advises farmers on the environment are necessary.

Coal and peat were responsible for 11% of all energy-related $CO_2$ emissions, mostly from electricity generation and in homes. Transport emissions accounts for over 40% of energy related C02 emissions. Chris Conway, stated "Obviously things like the cost-of-living crisis, COVID-19, the Ukraine War - all these things are dominating the news at the minute, but really, this [climate crisis] still is the largest crisis we face in the long-term, and we're very focused on making sure we address sustainable transport" (Cullen 2022).

As "up to 30% of emissions are within the scope and influence of local authorities in the UK" (Guinn 2022), many citizens believe that the government needs to do more to stop further environmental damage. A Climate Change Bill

gained Royal Assent in June 2022. NI's first Climate Action Plan coming from the bill is due to be published at the end of December 2023. It will contain targets for reductions in each of the highest emitting sectors, agriculture, transport, and energy.

## Conclusions

R.Q. 1: "Is the stagnant state of NI's government hindering efforts to reform the healthcare system?"

Throughout this research it was observed firsthand the bigger issues and complications that people face daily. The growth of healthcare needs has surpassed current medical capacity leaving patients dissatisfied. Doctors and nurses are overworked, unfairly remunerated, and offered no incentives or motivation. There are not enough workers, supplies, or infrastructure to give everyone the attention and medical care needed, resulting in appointments and surgeries canceled or rescheduled as neglected patients worsen their conditions over time.

Several factors led to conclude that the unstable government is majorly distressing the healthcare system.

Firstly, the stagnant state of NI's administration is having a significant impact on the ability to reform the healthcare system. It could be argued that this requires the full power of a steady government, as an alternative to one marginally available and sporadic. The state of political stalemate, that has been lasting for several years, has had a knock-on effect on a healthcare system that lacks investments in infrastructure, staffing, and equipment.

Secondly, although it is necessary a new integrated approach, with better coordination between providers and professionals, it seems like no one can step in to look after hospitals, facilities, and the outdated equipment that operates in borderline conditions.

Lastly, the external environment in the UK contributes to exacerbate the problem.

R.Q. 2: "What effect does the lack of strong institutions in the NI government have on its current peace process and justice system?"

Significant polarization has been present since the signing of the GFA, and more recently manifested as disagreements between Sinn Fein and the DUP. While one consequence of the political stalemate was the lack of progress at addressing key issues, such as the cost-of-living, education, crime, and even upholding the statutes of the GFA; another could be prompting unrest. As stated by an anonymous citizen, "Politicians let one subject that they can't agree on to stop them from talking about any of the issues that really matter."

The lack of strong institutions in NI' government had a profound detrimental effect on its peace process and justice system. While some EU initiatives have helped to build positive intercommunity relationships and promoted ideals of

peace in place of violence, it is still an ongoing struggle to unify two sides of a hurting nation and overcome the obstacles of divided leadership.

However, local citizens appear to be optimistic about the prospect of long-lasting peace. When walking around the city, it seems like people wish to live peacefully and to be reconciled with each other. Particularly, Gen-Z has been speaking out concerns about older generations values.

Although divided perspectives and ideals have contributed to weak institutions in the NI government, as people gradually become more tolerant, there is a chance for those institutions to improve and solidify. Nevertheless, external influences as Brexit or Scottish Independence could add stress, affecting the process of convergence.

R.Q. 3: "In what ways is NI behind the rest of the UK in its climate action plan, and why is that?"

Since the issuing of the first UK Climate Change Act (2008), NI stood in a period of political drought and insufficient action. Belfast has drafted, "Belfast's Resilience Assessment" which includes several matters that the city intends to improve upon, one of them being climate change (Belfast Council City 2020). The programs that are set out to make a change are receiving funding from the city's Resilience and Sustainability Board to make progress towards the city's overarching goal of a, "transition to an inclusive, net-zero emissions economy in a generation." To organize this monumental shift, the Belfast City Council has separated their tasks into three categories: Climate Adaptation and Mitigation; Participation of Children and Young People; and Connected, Net-Zero Emissions Economy. In early 2022 a UK Climate Change Risk Assessment (2022) was published, and a new UK Climate Change Act (NI) (2022) aimed to reduce greenhouse gasses, provided a system for carbon budgeting, and give power to public bodies to report information on climate change.

While NI seems to struggle most significantly in the areas of farming techniques, ocean protection, and public transportation, government shutdown and non-cooperation of some members of the community is delaying the process to combat climate change. Farmers fear new regulations carrying penalties and higher business costs. Cullen (2022) stated, "the [NI] committee doesn't believe NI will achieve net zero at the same time as the rest of the UK because of its economic dependence on agriculture."

HYPOTHESIS: "The lack of a stable government, caused by lasting sectarian division, is upholding these problems, and constraining people from cooperation."

As the stagnant state of NI's government is having a significant negative impact on the healthcare system, the peace process and justice system, climate action, and the overall quality of life, the hypothesis is confirmed.

People are suffering due to the government's lack of action and instability due to sectarian conflicts. Nowadays, tensions are no longer high, but many citizens are nervous to test the waters and to cause any riffs between the different parties.

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