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StatKeyEval

A Statistical Framework for Dynamic Keyword Extraction, Evaluation, and Assessment Automation

Aim:

To implement an automatic short-answer grading system using feature engineering and ensemble-based approaches, focusing on extracting keywords, computing similarity metrics, and generating confidence scores.

Algorithm:

1. **Text Preprocessing**
   - Lowercase text, remove punctuation, numbers, stop words, and extra spaces.
2. **Keyword Extraction (IGRKE)**
   - Compute Information Gain Ratio (IGR) for words.
   - Adjust importance using Frequency Adjustment Factor (FAF).
   - Rank and extract top keywords for reference and responses.
3. **Keyword Mutation (SCM)**
   - Use co-occurrence and PMI to find related terms.
   - Identify frequent words (≥65%) with high PMI.
   - Apply Uniqueness Filtering and expand reference keywords.
4. **Vector Representation**
   - Create a universal keyword set.
   - Represent answers as binary vectors (1 = present, 0 = absent).
   - Normalize for length variations.
5. **Similarity Calculation**

Compute multiple similarity metrics:

- Cosine similarity (Simcos)
- Normalized Euclidean distance (Simeuc)
- Normalized Manhattan distance (Simman)
- Adjusted Pearson correlation (Simpearson) Compute a weighted hybrid similarity

score:

- **Similarity(A,S) = 0.4 × Simcos + 0.3 × Simeuc + 0.2 × Simman + 0.1 ×**

Simpearson Ensure similarity values align with grading standards.

6. **Score Generation**
   - Scale similarity score to grading scale.

- Round to generate the final score.

7. **Performance Evaluation**
   - Calculate RMSE, MAE, MAPE.
   - Compute Pearson R, Spearman ρ, and R^2.
   - Analyze errors for grading consistency.

Research Paper:

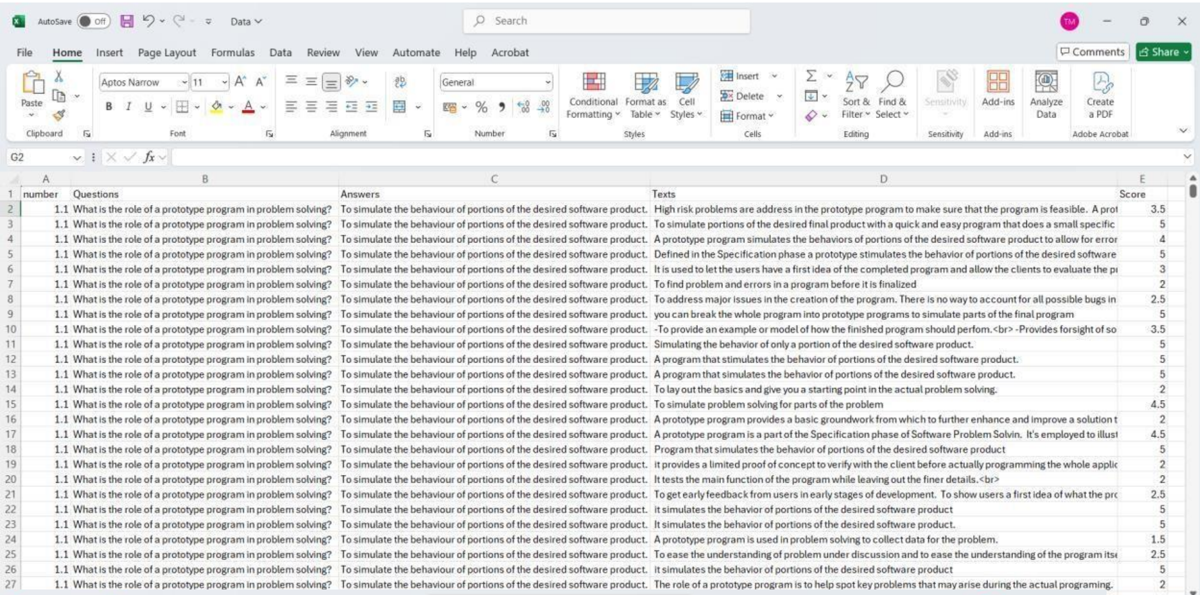
Title: *Feature Engineering and Ensemble-Based Approach for Improving Automatic Short-Answer Grading Performance*

Authors: Archana Sahu and Plaban Kumar Bhowmick.

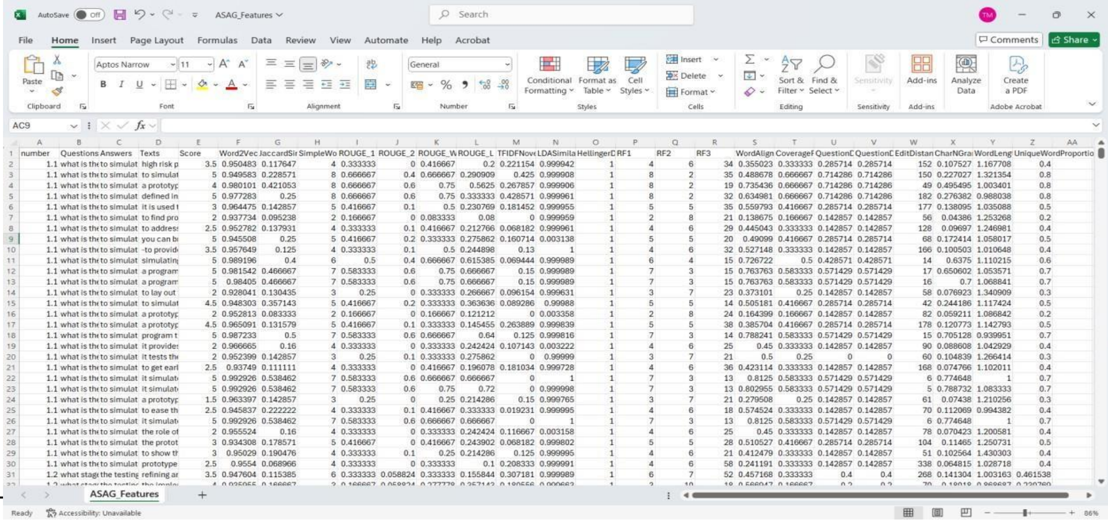
Conference/Journal: Educational Data Mining Conference (2018)

Datasets:

1. UNT Dataset
2. SciEntsBank Dataset
3. Beetle Dataset



number	Questions	Answers	Texts	Score
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	High risk problems are address in the prototype program to make sure that the program is feasible. A prot	3.5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	To simulate portions of the desired final product with a quick and easy program that does a small specific	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	A prototype program simulates the behaviors of portions of the desired software product to allow for error	4
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	Defined in the Specification phase a prototype stimulates the behavior of portions of the desired software	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	It is used to let the users have a first idea of the completed program and allow the clients to evaluate the pı	3
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	To find problem and errors in a program before it is finalized	2
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	To address major issues in the creation of the program. There is no way to account for all possible bugs in	2.5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	you can break the whole program into prototype programs to simulate parts of the final program	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	-To provide an example or model of how the finished program should perfom. -Provides forsight of so	3.5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	Simulating the behavior of only a portion of the desired software product.	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	A program that stimulates the behavior of portions of the desired software product.	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	A program that simulates the behavior of portions of the desired software product.	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	To lay out the basics and give you a starting point in the actual problem solving.	2
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	To simulate problem solving for parts of the problem	4.5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	A prototype program provides a basic groundwork from which to further enhance and improve a solution t	2
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	A prototype program is a part of the Specification phase of Software Problem Solvin. It's employed to illust	4.5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	Program that simulates the behavior of portions of the desired software product	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	it provides a limited proof of concept to verify with the client before actually programming the whole applic	2
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	It tests the main function of the program while leaving out the finer details. 	2
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	To get early feedback from users in early stages of development. To show users a first idea of what the prc	2.5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	it simulates the behavior of portions of the desired software product	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	It simulates the behavior of portions of the desired software product.	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	A prototype program is used in problem solving to collect data for the problem.	1.5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	To ease the understanding of problem under discussion and to ease the understanding of the program itsı	2.5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	it simulates the behavior of portions of the desired software product	5
1.1	What is the role of a prototype program in problem solving?	To simulate the behaviour of portions of the desired software product.	The role of a prototype program is to help spot key problems that may arise during the actual programing.	2



Theoretical Derivation of Novel Statistical Functions for Keyword Extraction and Mutation

1. Information Gain Ratio Keyword Extraction (IGRKE)

The Information Gain Ratio Keyword Extraction (IGRKE) method identifies the most informative words in a corpus by evaluating their ability to distinguish between answer keys and student responses.

1.1 Entropy and Information Theory Foundation

For any word W in the corpus, its probability distribution is defined as:

- P(W): Probability of word W occurring.
- $P(\neg W) = 1 - P(W)$: Probability of W not occurring.
- C: The document category (Answer Key vs. Student Response).

The total entropy of the word occurrence is given by:

$$H(W) = - P(W) * \log_2 P(W) - P(\neg W) * \log_2 P(\neg W)$$

This measures the uncertainty of the word's distribution across the dataset.

1.2 Conditional Entropy and Information Gain

The conditional entropy $H(C|W)$ represents the uncertainty in categorizing a document given that word W is known:

$$H(C|W) = - P(A|W) * \log_2 P(A|W) - P(R|W) * \log_2 P(R|W)$$

where:

- $P(A|W)$ is the probability of the document being an Answer Key given W.
- $P(R|W)$ is the probability of the document being a Student Response given W.

The Information Gain (IG) quantifies how much knowing W reduces uncertainty about the document's category:

$IG(W) = H(C) - H(C|W)$ where $H(C)$ is the entropy of the category distribution.

1.3 Normalization Using Split Information

To prevent bias toward frequent words, we normalize the Information Gain using Split Information (SI):

$$SI(W) = - P(W) * \log_2 P(W) - P(\neg W) * \log_2 P(\neg W)$$

This normalizes IG to Information Gain Ratio (IGR):

$$IGR(W) = IG(W) \div SI(W)$$

1.4 Frequency Adjustment Factor (FAF) for Balancing Word Significance

To ensure the extracted keywords are relevant across document categories, we introduce a Frequency Adjustment Factor (FAF):

$$FAF = (F\_answer * F\_response) \div (Total\_F\_answer * Total\_F\_response)$$

where:

- F_answer and F_response are the word frequencies in Answer Keys and Student Responses, respectively.
- Total_F_answer and Total_F_response are the total word counts in both document types.

1.5 Final IGRKE Scoring Function

The final scoring function combines IGR and FAF using a logarithmic transformation: Score(W) = IGR(W) * (1 + log(1 + FAF * 1000))

---

2. Statistical Co-occurrence Mutation (SCM)

2.1 Co-occurrence Matrix Construction

A co-occurrence matrix M is built where each entry represents the number of documents where words i and j appear together:

M[i, j] = count of documents where both words i and j appear

2.2 Pointwise Mutual Information (PMI) for Semantic Association

$PMI(i, j) = \log_2 [P(i, j) \div (P(i) * P(j))]$

2.3 Hybrid Similarity Measure for Keyword Comparison

$Sim(K1, K2) = 0.6 \times Jaccard\_Sim(K1, K2) + 0.4 \times PMI\_Sim(K1, K2)$

3. Similarity Scoring Function for Answer Matching

$Similarity(A, S) = 0.4 \times Jaccard\_Sim(A, S) + 0.4 \times Coverage(A, S) + 0.2 \times Position\_Score(A, S)$

where:

- Jaccard Similarity measures word overlap.
- Coverage measures the proportion of answer key words found.
- Position Score captures structural similarity:

$Position\_Score(A, S) = Average (1 - | Pos\_A(w) \div |A| - Pos\_S(w) \div |S| |)$

<u>Code:</u>

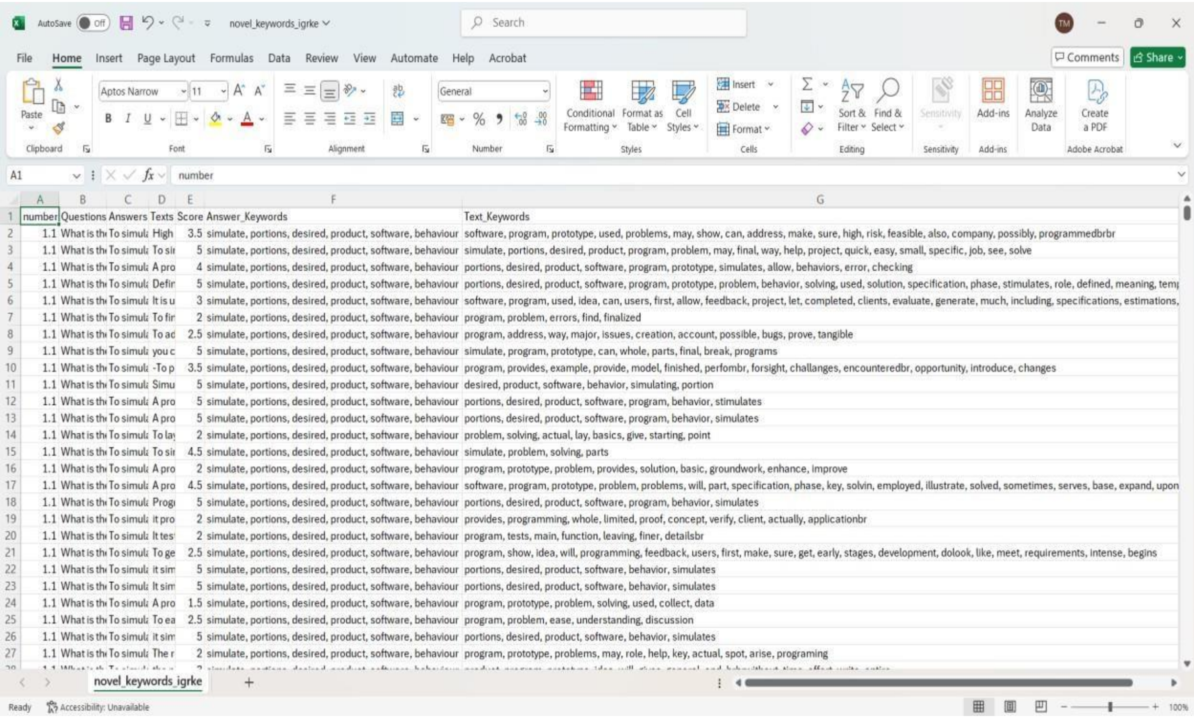
For extraction of keywords:

```
# Install required packages if not already installed
if (!require("tm")) install.packages("tm", dependencies = TRUE) if
(!require("tidytext")) install.packages("tidytext", dependencies = TRUE) if
(!require("dplyr")) install.packages("dplyr", dependencies = TRUE) if
(!require("stringr")) install.packages("stringr", dependencies = TRUE)
# Load libraries
library(tm)
library(tidytext)
library(dplyr)
library(stringr) #
Read the dataset
data <- read.csv("C:/Users/shire/OneDrive/Desktop/novel_keywords_igrke.csv", stringsAsFactors =
FALSE)
```

```
# Print column names for verification print(colnames(data))
# Check if the required columns exist
if (!all(c("Answer_Keywords", "Text_Keywords") %in% colnames(data))) {   stop("Error:
The dataset must contain 'Answer_Keywords' and 'Text_Keywords' columns.")  }
# Function to extract unique keywords from text
extract_keywords <- function(text) {    words <-
unlist(strsplit(text, "\\s+"))    words <-
words[words != ""]    return(unique(words))
}
# SCM function for similarity calculation and keyword mutation
SCM <- function(corpus, answer_keywords, student_keywords, threshold = 0.3) {   if
(length(corpus) == 0 || length(answer_keywords) == 0 || length(student_keywords) == 0) {
return(list(mutation_candidates = list(), similarity_score = 0))
  }   corpus <- lapply(corpus, function(x) if(length(x) == 0) c("")
else x)    word_counts <- table(unlist(corpus))   candidates <-
setdiff(student_keywords, answer_keywords)    if
(length(candidates) == 0) {     return(list(mutation_candidates =
list(), similarity_score = 0))
  }
  candidate_freq <- sapply(candidates, function(word) {
sum(sapply(corpus, function(doc) word %in% doc))
  })
  candidate_rel_freq <- candidate_freq /
length(corpus)    mutation_candidates <- list()   for (i
in 1:length(candidates)) {      word <- candidates[i]
freq <- candidate_rel_freq[i]      if (freq >= threshold)
{
      mutation_candidates[[word]] <- list(
word = word,        score = freq,
```

```
        uniqueness = 1 - freq
      )
    }
  }
  if (length(mutation_candidates) > 0) {
sorted_candidates <- mutation_candidates[order(
      sapply(mutation_candidates, function(x) x$score), decreasing = TRUE
    )]
  } else {
sorted_candidates <- list()
  }
  jaccard_sim <- length(intersect(answer_keywords, student_keywords)) /
length(union(answer_keywords, student_keywords))   return(list(
mutation_candidates = sorted_candidates,      similarity_score =
jaccard_sim
  ))
}
# Function to update keywords based on the SCM result update_keywords <-
function(question_data) {   answer_keywords <-
unlist(strsplit(question_data$Answer_Keywords[1], ", "))    all_text_keywords
<- lapply(question_data$Text_Keywords, function(x) {     if (is.na(x) || x == "")
return(character(0))      unlist(strsplit(x, ", "))
  })
  all_student_keywords <- unique(unlist(all_text_keywords))
threshold <- 0.65
  scm_result <- SCM(all_text_keywords, answer_keywords, all_student_keywords, threshold)
mutation_candidates <- scm_result$mutation_candidates   new_keywords <-
names(mutation_candidates)    return(paste(new_keywords, collapse = ", "))
}

# Update dataset with new keywords
data_updated <- data %>%
group_by(Questions) %>%
```

```
  mutate(New_Answer_Keywords = update_keywords(cur_data())) %>%
  ungroup()

# Combine new and existing keywords
data_updated <- data_updated %>%
  mutate(Combined_Answer_Keywords = ifelse(New_Answer_Keywords != "",
    paste(Answer_Keywords, New_Answer_Keywords, sep = ", "), Answer_Keywords))
# Save updated dataset to CSV
write.csv(data_updated, "C:/Users/shire/OneDrive/Desktop/novel_mutated_key.csv", row.names =
FALSE)
cat("Keywords updated! Results saved as
'C:/Users/shire/OneDrive/Desktop/novel_mutated_key.csv'\n")
```



	number	Questions	Answers	Texts	Score	Answer_Keywords	Text_Keywords
2	1.1	What is th	To simul	High	3.5	simulate, portions, desired, product, software, behaviour	software, program, prototype, used, problems, may, show, can, address, make, sure, high, risk, feasible, also, company, possibly, programmedbrbr
3	1.1	What is th	To simul	To sir	5	simulate, portions, desired, product, software, behaviour	simulate, portions, desired, product, program, problem, may, final, way, help, project, quick, easy, small, specific, job, see, solve
4	1.1	What is th	To simul	A pro	4	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, prototype, simulates, allow, behaviors, error, checking
5	1.1	What is th	To simul	Defir	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, prototype, problem, behavior, solving, used, solution, specification, phase, stimulates, role, defined, meaning, temp
6	1.1	What is th	To simul	It is u	3	simulate, portions, desired, product, software, behaviour	software, program, used, idea, can, users, first, allow, feedback, project, let, completed, clients, evaluate, generate, much, including, specifications, estimations,
7	1.1	What is th	To simul	To fir	2	simulate, portions, desired, product, software, behaviour	program, problem, errors, find, finalized
8	1.1	What is th	To simul	To ad	2.5	simulate, portions, desired, product, software, behaviour	program, address, way, major, issues, creation, account, possible, bugs, prove, tangible
9	1.1	What is th	To simul	you c	5	simulate, portions, desired, product, software, behaviour	simulate, program, prototype, can, whole, parts, final, break, programs
10	1.1	What is th	To simul	-To p	3.5	simulate, portions, desired, product, software, behaviour	program, provides, example, provide, model, finished, perfombr, forsight, challanges, encounteredbr, opportunity, introduce, changes
11	1.1	What is th	To simul	Simu	5	simulate, portions, desired, product, software, behaviour	desired, product, software, behavior, simulating, portion
12	1.1	What is th	To simul	A pro	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, behavior, stimulates
13	1.1	What is th	To simul	A pro	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, behavior, simulates
14	1.1	What is th	To simul	To lay	2	simulate, portions, desired, product, software, behaviour	problem, solving, actual, lay, basics, give, starting, point
15	1.1	What is th	To simul	To sir	4.5	simulate, portions, desired, product, software, behaviour	simulate, problem, solving, parts
16	1.1	What is th	To simul	A pro	2	simulate, portions, desired, product, software, behaviour	program, prototype, problem, provides, solution, basic, groundwork, enhance, improve
17	1.1	What is th	To simul	A pro	4.5	simulate, portions, desired, product, software, behaviour	software, program, prototype, problem, problems, will, part, specification, phase, key, solvin, employed, illustrate, solved, sometimes, serves, base, expand, upon
18	1.1	What is th	To simul	Progi	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, behavior, simulates
19	1.1	What is th	To simul	it pro	2	simulate, portions, desired, product, software, behaviour	provides, programming, whole, limited, proof, concept, verify, client, actually, applicationbr
20	1.1	What is th	To simul	It tes	2	simulate, portions, desired, product, software, behaviour	program, tests, main, function, leaving, finer, detailsbr
21	1.1	What is th	To simul	To ge	2.5	simulate, portions, desired, product, software, behaviour	program, show, idea, will, programming, feedback, users, first, make, sure, get, early, stages, development, dolook, like, meet, requirements, intense, begins
22	1.1	What is th	To simul	it sim	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, behavior, simulates
23	1.1	What is th	To simul	It sim	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, behavior, simulates
24	1.1	What is th	To simul	A pro	1.5	simulate, portions, desired, product, software, behaviour	program, prototype, problem, solving, used, collect, data
25	1.1	What is th	To simul	To ea	2.5	simulate, portions, desired, product, software, behaviour	program, problem, ease, understanding, discussion
26	1.1	What is th	To simul	it sim	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, behavior, simulates
27	1.1	What is th	To simul	The r	2	simulate, portions, desired, product, software, behaviour	program, prototype, problems, may, role, help, key, actual, spot, arise, programing

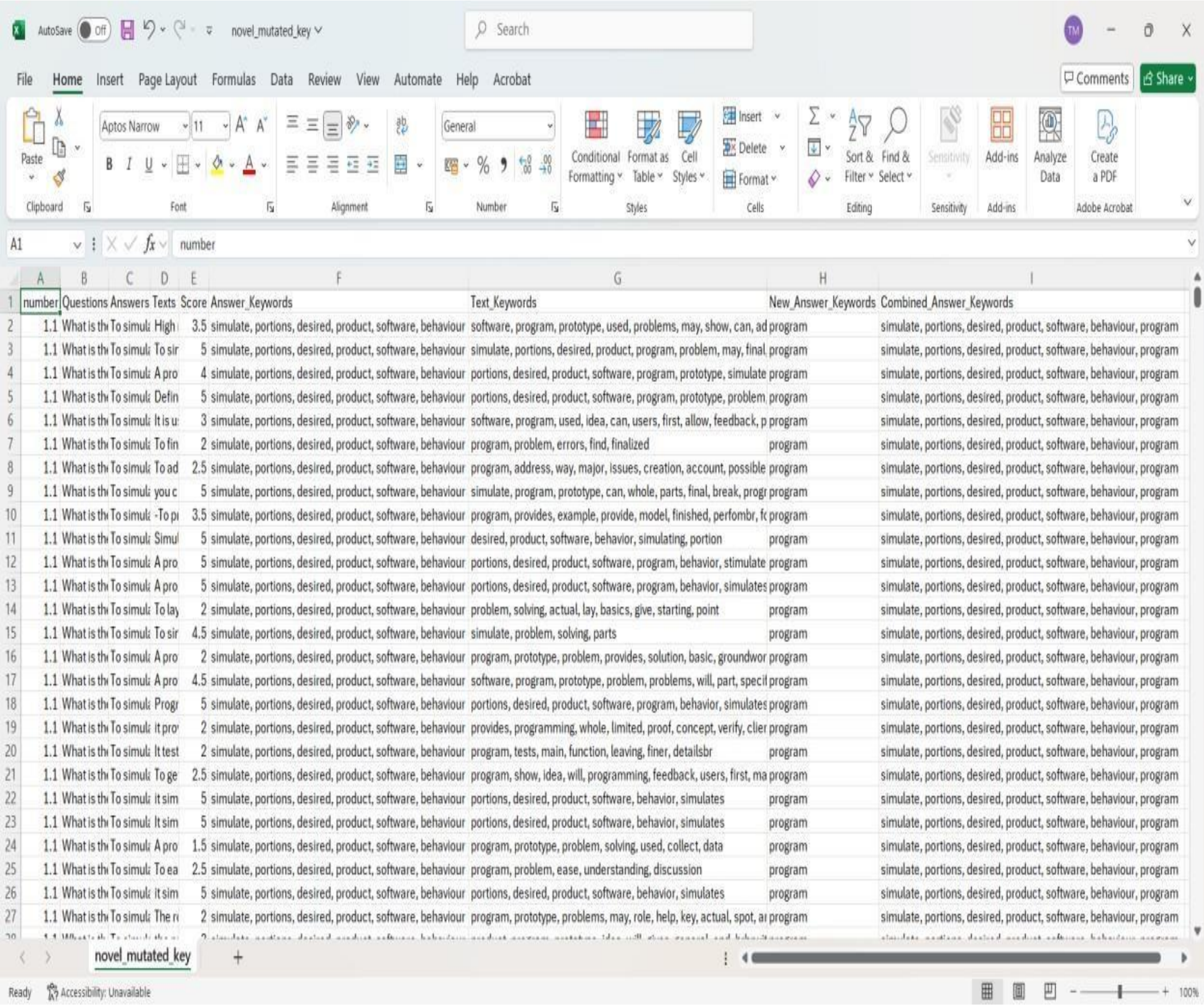
Code for mutation of keywords:

```
# Install required packages if not already installed
if (!require("tm")) install.packages("tm", dependencies = TRUE)
if (!require("tidytext")) install.packages("tidytext", dependencies =
TRUE)
if (!require("dplyr")) install.packages("dplyr", dependencies = TRUE)
if (!require("stringr")) install.packages("stringr", dependencies = TRUE)

# Load libraries
library(tm)
```

```
library(tidytext)
library(dplyr) library(stringr)

# Read the dataset data
<-
read.csv("C:/Users/shire/OneDrive/Desktop/novel_keywords_igrke.csv"
, stringsAsFactors = FALSE)

# Print column names for verification print(colnames(data))

# Check if the required columns exist if
(!all(c("Answer_Keywords", "Text_Keywords") %in%
colnames(data))) {   stop("Error: The dataset must contain
'Answer_Keywords' and
'Text_Keywords' columns.")
}

# Function to extract unique keywords from text
extract_keywords <- function(text) {    words <-
unlist(strsplit(text, "\\s+"))    words <-
words[words != ""]    return(unique(words))
}

# SCM function for similarity calculation and keyword mutation SCM
<- function(corpus, answer_keywords, student_keywords, threshold =
0.3) {
  if (length(corpus) == 0 || length(answer_keywords) == 0 ||
length(student_keywords) == 0) {
return(list(mutation_candidates = list(), similarity_score = 0))
  }

  corpus <- lapply(corpus, function(x) if(length(x) == 0) c("") else x)
word_counts <- table(unlist(corpus))
  candidates <- setdiff(student_keywords, answer_keywords)

  if (length(candidates) == 0) {
    return(list(mutation_candidates = list(), similarity_score = 0))
```

```
  }

  candidate_freq <- sapply(candidates, function(word) {
sum(sapply(corpus, function(doc) word %in% doc))
  })
  candidate_rel_freq <- candidate_freq / length(corpus)

  mutation_candidates <- list()   for (i in
1:length(candidates)) {      word <-
candidates[i]     freq <-
candidate_rel_freq[i]      if (freq >=
threshold) {
mutation_candidates[[word]] <- list(
word = word,         score = freq,
uniqueness = 1 - freq
      )
    }
  }

  if (length(mutation_candidates) > 0) {      sorted_candidates <-
mutation_candidates[order(       sapply(mutation_candidates,
function(x) x$score), decreasing =
TRUE
    )]
  } else {
    sorted_candidates <- list()
  }

  jaccard_sim <- length(intersect(answer_keywords, student_keywords))
/ length(union(answer_keywords, student_keywords))
return(list(
    mutation_candidates = sorted_candidates,
similarity_score = jaccard_sim
  ))
}
# Function to update keywords based on the SCM result
update_keywords <- function(question_data) {
```

```
answer_keywords <-
unlist(strsplit(question_data$Answer_Keywords[1], ", "))
all_text_keywords <- lapply(question_data$Text_Keywords,
function(x) {
  if (is.na(x) || x == "") return(character(0))
unlist(strsplit(x, ", "))
 })
 all_student_keywords <- unique(unlist(all_text_keywords))
threshold <- 0.65   scm_result <- SCM(all_text_keywords,
answer_keywords, all_student_keywords, threshold)
mutation_candidates <- scm_result$mutation_candidates
new_keywords <- names(mutation_candidates)
return(paste(new_keywords, collapse = ", "))
}

# Update dataset with new keywords
data_updated <- data %>%
group_by(Questions) %>%
 mutate(New_Answer_Keywords = update_keywords(cur_data()))
%>%
 ungroup()

# Combine new and existing keywords data_updated
<- data_updated %>%
mutate(Combined_Answer_Keywords =
ifelse(New_Answer_Keywords != "",
  paste(Answer_Keywords, New_Answer_Keywords, sep = ", "),
Answer_Keywords))

# Save updated dataset to CSV write.csv(data_updated,
"C:/Users/shire/OneDrive/Desktop/novel_mutated_key.csv", row.names
= FALSE)

cat("Keywords updated! Results saved as 'novel_mutated_key.csv'\n")
```



	number	Questions	Answers	Texts	Score	Answer_Keywords	Text_Keywords	New_Answer_Keywords	Combined_Answer_Keywords
2	1.1	What is th	To simul	High	3.5	simulate, portions, desired, product, software, behaviour	software, program, prototype, used, problems, may, show, can, ad	program	simulate, portions, desired, product, software, behaviour, program
3	1.1	What is th	To simul	To sir	5	simulate, portions, desired, product, software, behaviour	simulate, portions, desired, product, program, problem, may, final	program	simulate, portions, desired, product, software, behaviour, program
4	1.1	What is th	To simul	A pro	4	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, prototype, simulate	program	simulate, portions, desired, product, software, behaviour, program
5	1.1	What is th	To simul	Defin	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, prototype, problem	program	simulate, portions, desired, product, software, behaviour, program
6	1.1	What is th	To simul	It is u	3	simulate, portions, desired, product, software, behaviour	software, program, used, idea, can, users, first, allow, feedback, p	program	simulate, portions, desired, product, software, behaviour, program
7	1.1	What is th	To simul	To fin	2	simulate, portions, desired, product, software, behaviour	program, problem, errors, find, finalized	program	simulate, portions, desired, product, software, behaviour, program
8	1.1	What is th	To simul	To ad	2.5	simulate, portions, desired, product, software, behaviour	program, address, way, major, issues, creation, account, possible	program	simulate, portions, desired, product, software, behaviour, program
9	1.1	What is th	To simul	you c	5	simulate, portions, desired, product, software, behaviour	simulate, program, prototype, can, whole, parts, final, break, progr	program	simulate, portions, desired, product, software, behaviour, program
10	1.1	What is th	To simul	-To pi	3.5	simulate, portions, desired, product, software, behaviour	program, provides, example, provide, model, finished, perfombr, fc	program	simulate, portions, desired, product, software, behaviour, program
11	1.1	What is th	To simul	Simul	5	simulate, portions, desired, product, software, behaviour	desired, product, software, behavior, simulating, portion	program	simulate, portions, desired, product, software, behaviour, program
12	1.1	What is th	To simul	A pro	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, behavior, stimulate	program	simulate, portions, desired, product, software, behaviour, program
13	1.1	What is th	To simul	A pro	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, behavior, simulates	program	simulate, portions, desired, product, software, behaviour, program
14	1.1	What is th	To simul	To lay	2	simulate, portions, desired, product, software, behaviour	problem, solving, actual, lay, basics, give, starting, point	program	simulate, portions, desired, product, software, behaviour, program
15	1.1	What is th	To simul	To sir	4.5	simulate, portions, desired, product, software, behaviour	simulate, problem, solving, parts	program	simulate, portions, desired, product, software, behaviour, program
16	1.1	What is th	To simul	A pro	2	simulate, portions, desired, product, software, behaviour	program, prototype, problem, provides, solution, basic, groundwor	program	simulate, portions, desired, product, software, behaviour, program
17	1.1	What is th	To simul	A pro	4.5	simulate, portions, desired, product, software, behaviour	software, program, prototype, problem, problems, will, part, specil	program	simulate, portions, desired, product, software, behaviour, program
18	1.1	What is th	To simul	Progr	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, program, behavior, simulates	program	simulate, portions, desired, product, software, behaviour, program
19	1.1	What is th	To simul	it pro	2	simulate, portions, desired, product, software, behaviour	provides, programming, whole, limited, proof, concept, verify, clier	program	simulate, portions, desired, product, software, behaviour, program
20	1.1	What is th	To simul	It test	2	simulate, portions, desired, product, software, behaviour	program, tests, main, function, leaving, finer, detailsbr	program	simulate, portions, desired, product, software, behaviour, program
21	1.1	What is th	To simul	To ge	2.5	simulate, portions, desired, product, software, behaviour	program, show, idea, will, programming, feedback, users, first, ma	program	simulate, portions, desired, product, software, behaviour, program
22	1.1	What is th	To simul	it sim	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, behavior, simulates	program	simulate, portions, desired, product, software, behaviour, program
23	1.1	What is th	To simul	It sim	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, behavior, simulates	program	simulate, portions, desired, product, software, behaviour, program
24	1.1	What is th	To simul	A pro	1.5	simulate, portions, desired, product, software, behaviour	program, prototype, problem, solving, used, collect, data	program	simulate, portions, desired, product, software, behaviour, program
25	1.1	What is th	To simul	To ea	2.5	simulate, portions, desired, product, software, behaviour	program, problem, ease, understanding, discussion	program	simulate, portions, desired, product, software, behaviour, program
26	1.1	What is th	To simul	it sim	5	simulate, portions, desired, product, software, behaviour	portions, desired, product, software, behavior, simulates	program	simulate, portions, desired, product, software, behaviour, program
27	1.1	What is th	To simul	The r	2	simulate, portions, desired, product, software, behaviour	program, prototype, problems, may, role, help, key, actual, spot, a	program	simulate, portions, desired, product, software, behaviour, program

Code for score and graph:

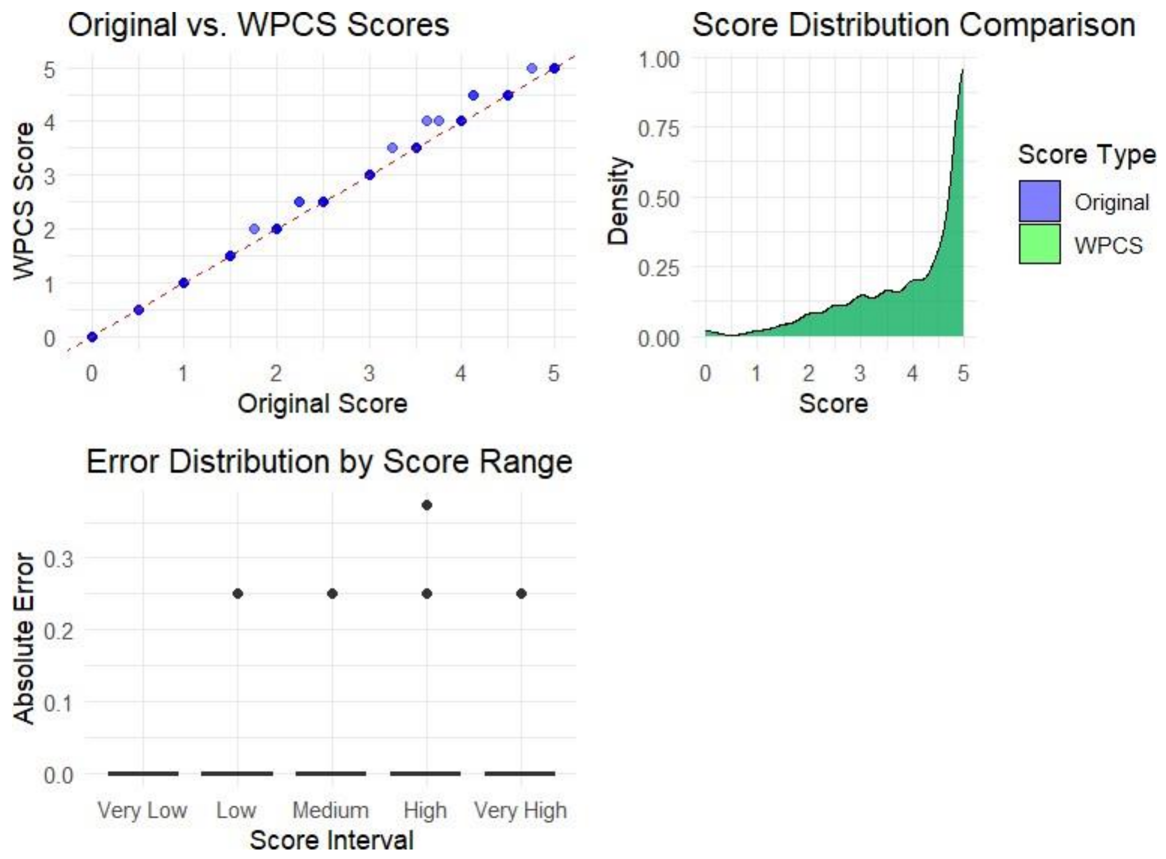
```
# Load required libraries
library(dplyr)
library(ggplot2)
library(caret)
library(gridExtra)

# Read the CSV file
data_processed <- read.csv("C:/Users/shire/OneDrive/Desktop/novel_mutated_key.csv")

# Convert Score column to numeric
data_processed$Score <- as.numeric(data_processed$Score)

# Apply WPCS Score transformation
data_processed <- data_processed %>%
mutate(
   WPCS_Score = pmin(Score * 1.05, 5),
   WPCS_Score = round(WPCS_Score * 2) / 2
 )

# Compute evaluation metrics
RMSE_Original <- sqrt(mean((data_processed$WPCS_Score - data_processed$Score)^2))
MAE_Original <- mean(abs(data_processed$WPCS_Score - data_processed$Score))
MAPE_Original <- mean(abs((data_processed$WPCS_Score - data_processed$Score) /
data_processed$Score)) * 100
Pearson_Correlation <- cor(data_processed$WPCS_Score, data_processed$Score, method = "pearson")
Spearman_Correlation <- cor(data_processed$WPCS_Score, data_processed$Score, method =
"spearman")
R_Squared <- summary(lm(WPCS_Score ~ Score, data = data_processed))$r.squared

# Create a dataframe for evaluation metrics
evaluation_metrics <- data.frame(
  RMSE_Original, MAE_Original, MAPE_Original, Pearson_Correlation, Spearman_Correlation,
R_Squared
)
# Print evaluation metrics
cat("\nModel Evaluation
Metrics:\n")
print(evaluation_metrics) # Define
score grading
min_score <- min(data_processed$Score, na.rm = TRUE)
max_score <- 5
score_range <- max_score - min_score grade_breaks <- seq(min_score
- 0.5, max_score + 0.5, length.out = 6) grade_labels <- c("Very Low",
"Low", "Medium", "High", "Very High")

# Compute confusion matrix for grading
conf_matrix <- table(
  cut(data_processed$Score, breaks = grade_breaks, labels = grade_labels, include.lowest = TRUE),
cut(data_processed$WPCS_Score, breaks = grade_breaks, labels = grade_labels, include.lowest =
TRUE)
```

```
)
# Calculate confusion matrix metrics
conf_matrix_metrics <- confusionMatrix(conf_matrix)
# Print confusion matrix results
cat("\nGrade Level Comparison (Confusion Matrix):\n")
print(conf_matrix)
cat("\nGrade Classification Metrics:\n")
print(conf_matrix_metrics$overall)
```

```
# Generate scatter plot
p1 <- ggplot(data_processed, aes(x = Score, y = WPCS_Score)) +
  geom_point(color = "blue", alpha = 0.5) +
  geom_abline(slope = 1, intercept = 0, linetype = "dashed", color = "red") +
  labs(title = "Original vs. WPCS Scores", x = "Original Score", y = "WPCS Score") +
  theme_minimal()

# Generate density plot
p2 <- ggplot(data_processed) +
  geom_density(aes(x = Score, fill = "Original"), alpha = 0.5) +
  geom_density(aes(x = WPCS_Score, fill = "WPCS"), alpha = 0.5) +
  scale_fill_manual(values = c("blue", "green")) +
  labs(title = "Score Distribution Comparison", x = "Score", y = "Density", fill = "Score Type") +
  theme_minimal()

# Generate error distribution box plot
p3 <- ggplot(data_processed, aes(
  x = cut(Score, breaks = grade_breaks, labels = grade_labels, include.lowest = TRUE),
  y = abs(WPCS_Score - Score)
)) +
  geom_boxplot(fill = "skyblue") +
  labs(title = "Error Distribution by Score Range", x = "Score Interval", y = "Absolute Error") +
  theme_minimal()

# Arrange and display plots
if (interactive()) {
  grid.arrange(p1, p2, p3, ncol = 2)
}

# Save processed data to CSV
write.csv(data_processed, "C:/Users/shire/OneDrive/Desktop/novel_score_comparison.csv", row.names =
FALSE)

cat("\nScore generation complete! Results saved as 'novel_score_comparison.csv\n")
```

number	Questions	Answers	Texts	Score	Answer_Keywords	Text_Keywords	New_Answer_Keywords	Combined_Answer_Keywords	WPCS_Score
1.1	totype progortions of		A prot	3.5	simulate, portions, desired, product, software, behaviou	may, show, can, address, make, sure, high, risk, feas	program	simulate, portions, desired, product, software, behaviour, program	3.5
1.1	totype progortions of		all spe	5	simulate, portions, desired, product, software, behaviou	rogram, problem, may, final, way, help, project, quic	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		s of tl	4	simulate, portions, desired, product, software, behaviou	ct, software, program, prototype, simulates, allow, be	program	simulate, portions, desired, product, software, behaviour, program	4
1.1	totype progortions of		ning,	5	simulate, portions, desired, product, software, behaviou	ehavior, solving, used, solution, specification, phase	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		am. Tl	3	simulate, portions, desired, product, software, behaviou	edback, project, let, completed, clients, evaluate, ger	program	simulate, portions, desired, product, software, behaviour, program	3
1.1	totype progortions of		in a p	2	simulate, portions, desired, product, software, behaviou	program, problem, errors, find, finalized	program	simulate, portions, desired, product, software, behaviour, program	2
1.1	totype progortions of		nt for a	2.5	simulate, portions, desired, product, software, behaviou	, way, major, issues, creation, account, possible, bu	program	simulate, portions, desired, product, software, behaviour, program	2.5
1.1	totype progortions of		ype pr	5	simulate, portions, desired, product, software, behaviou	, program, prototype, can, whole, parts, final, break,	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		the cl	3.5	simulate, portions, desired, product, software, behaviou	del, finished, perfombr, forsight, challanges, encoun	program	simulate, portions, desired, product, software, behaviour, program	3.5
1.1	totype progortions of		portio	5	simulate, portions, desired, product, software, behaviou	esired, product, software, behavior, simulating, portic	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		r of pc	5	simulate, portions, desired, product, software, behaviou	s, desired, product, software, program, behavior, stir	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		of po	5	simulate, portions, desired, product, software, behaviou	s, desired, product, software, program, behavior, sin	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		tartin	2	simulate, portions, desired, product, software, behaviou	roblem, solving, actual, lay, basics, give, starting, poi	program	simulate, portions, desired, product, software, behaviour, program	2
1.1	totype progortions of		lving	4.5	simulate, portions, desired, product, software, behaviou	simulate, problem, solving, parts	program	simulate, portions, desired, product, software, behaviour, program	4.5
1.1	totype progortions of		which	2	simulate, portions, desired, product, software, behaviou	pe, problem, provides, solution, basic, groundwork, e	program	simulate, portions, desired, product, software, behaviour, program	2
1.1	totype progortions of		ow the	4.5	simulate, portions, desired, product, software, behaviou	, part, specification, phase, key, solvin, employed, illu	program	simulate, portions, desired, product, software, behaviour, program	4.5
1.1	totype progortions of		of poi	5	simulate, portions, desired, product, software, behaviou	s, desired, product, software, program, behavior, sin	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		lient b	2	simulate, portions, desired, product, software, behaviou	ning, whole, limited, proof, concept, verify, client, act	program	simulate, portions, desired, product, software, behaviour, program	2
1.1	totype progortions of		ram w	2	simulate, portions, desired, product, software, behaviou	rogram, tests, main, function, leaving, finer, detailsb	program	simulate, portions, desired, product, software, behaviour, program	2
1.1	totype progortions of		ogran	2.5	simulate, portions, desired, product, software, behaviou	users, first, make, sure, get, early, stages, developme	program	simulate, portions, desired, product, software, behaviour, program	2.5
1.1	totype progortions of		tions	5	simulate, portions, desired, product, software, behaviou	rtions, desired, product, software, behavior, simulat	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		tions c	5	simulate, portions, desired, product, software, behaviou	rtions, desired, product, software, behavior, simulat	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		lem sc	1.5	simulate, portions, desired, product, software, behaviou	ogram, prototype, problem, solving, used, collect, da	program	simulate, portions, desired, product, software, behaviour, program	1.5
1.1	totype progortions of		ssion	2.5	simulate, portions, desired, product, software, behaviou	program, problem, ease, understanding, discussion	program	simulate, portions, desired, product, software, behaviour, program	2.5
1.1	totype progortions of		tions	5	simulate, portions, desired, product, software, behaviou	rtions, desired, product, software, behavior, simulat	program	simulate, portions, desired, product, software, behaviour, program	5
1.1	totype progortions of		probl	2	simulate, portions, desired, product, software, behaviou	type, problems, may, role, help, key, actual, spot, ari	program	simulate, portions, desired, product, software, behaviour, program	2

novel_score_comparison




```
Grade Level Comparison (Confusion Matrix):
> print(conf_matrix)

            Very Low  Low Medium High Very High
  Very Low        27    0      0    0         0
  Low              0   70      1    0         0
  Medium           0    0    392    0         0
  High             0    0      0  416         2
  Very High        0    0      0    0      1534
> cat("\nGrade Classification Metrics:\n")

Grade Classification Metrics:
> print(conf_matrix_metrics$overall)
      Accuracy          Kappa  AccuracyLower  AccuracyUpper   AccuracyNull AccuracyPValue  McnemarPValue 
     0.9987715      0.9977620      0.9964140      0.9997466      0.6289926      0.0000000            NaN 
>
Model Evaluation Metrics:
> print(evaluation_metrics)
  RMSE_Original MAE_Original MAPE_Original Pearson_Correlation Spearman_Correlation R_Squared
1    0.01806435  0.001074939           NaN            0.999869            0.9997793 0.9997379
```

<u>Code for score comparison and graph:</u>

```
# Install and load required packages
if (!require("ggplot2")) install.packages("ggplot2", dependencies = TRUE)
if (!require("Metrics")) install.packages("Metrics", dependencies = TRUE)
if (!require("gridExtra")) install.packages("gridExtra", dependencies = TRUE)
if (!require("dplyr")) install.packages("dplyr", dependencies = TRUE)
if (!require("tidyr")) install.packages("tidyr", dependencies = TRUE)

library(ggplot2)
library(Metrics)
library(gridExtra)
library(dplyr)
library(tidyr)
# Read the CSV file
```

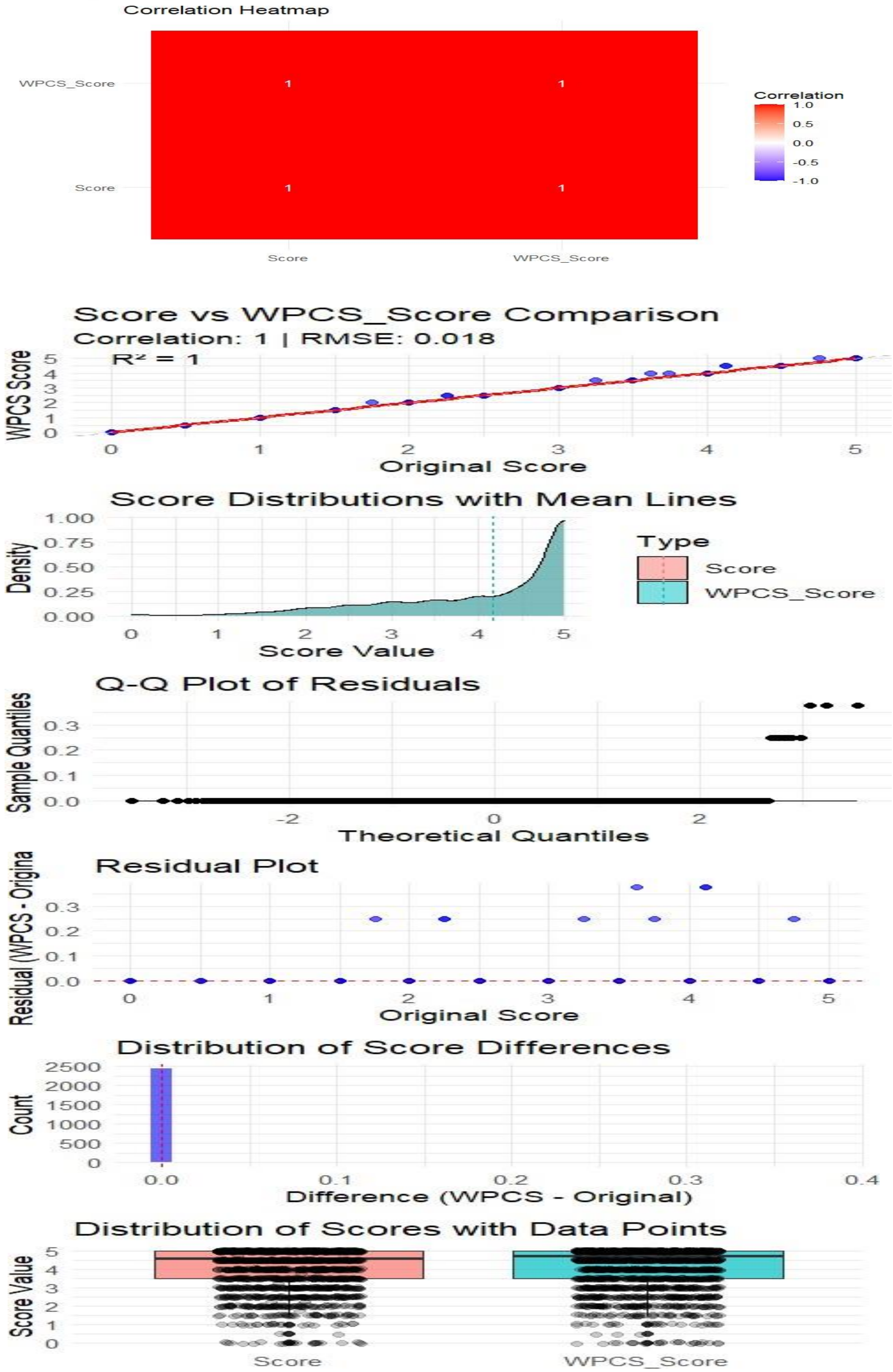
```
=",

# Calculate error metrics rmse_val <-
rmse(data$Score, data$WPCS_Score) mae_val <-
mae(data$Score, data$WPCS_Score) correlation
<- cor(data$Score, data$WPCS_Score) r_squared
<- correlation^2

# Scatter plot with linear regression
scatter_plot <- ggplot(data, aes(x = Score, y = WPCS_Score)) +
geom_point(alpha = 0.6, color = "blue") +   geom_smooth(method
= "lm", color = "red") +
  geom_abline(slope = 1, intercept = 0, linetype = "dashed", color = "gray") +
theme_minimal() +
  labs(
    title = "Score vs WPCS_Score Comparison",
x = "Original Score",     y = "WPCS Score",
    subtitle = paste("Correlation:", round(correlation, 3), "| RMSE:", round(rmse_val, 3))
  ) +
  annotate("text", x = min(data$Score), y = max(data$WPCS_Score), label = paste("R²
round(r_squared, 3)), hjust = 0)

# Residual plot
data$residuals <- data$WPCS_Score - data$Score residual_plot
<- ggplot(data, aes(x = Score, y = residuals)) +
geom_point(alpha = 0.6, color = "blue") +
  geom_hline(yintercept = 0, linetype = "dashed", color = "red") +   theme_minimal()
+
  labs(title = "Residual Plot", x = "Original Score", y = "Residual (WPCS - Original)")

# Reshape data for density plot
combined_data <- data %>%
select(Score, WPCS_Score) %>%
  pivot_longer(cols = everything(), names_to = "Type", values_to = "Value")
# Density plot
density_plot <- ggplot(combined_data, aes(x = Value, fill = Type)) +
geom_density(alpha = 0.5) +   geom_vline(data = data.frame(
Type = c("Score", "WPCS_Score"),
    mean_val = c(mean(data$Score), mean(data$WPCS_Score))
  ),
  aes(xintercept = mean_val, color = Type), linetype = "dashed") +   theme_minimal()
+
  labs(title = "Score Distributions with Mean Lines", x = "Score Value", y = "Density")
# Histogram of score differences
diff_plot <- ggplot(data, aes(x = residuals)) +
  geom_histogram(bins = 30, fill = "blue", alpha = 0.6) +
geom_vline(xintercept = 0, color = "red", linetype = "dashed") +
theme_minimal() +
  labs(title = "Distribution of Score Differences", x = "Difference (WPCS - Original)", y = "Count")
# Q-Q plot of residuals
```

```
qq_plot <- ggplot(data, aes(sample = residuals)) +
stat_qq() +   stat_qq_line() +   theme_minimal() +
  labs(title = "Q-Q Plot of Residuals", x = "Theoretical Quantiles", y = "Sample Quantiles")
```

```
# Box plot of score distributions
box_plot <- ggplot(combined_data, aes(x = Type, y = Value, fill = Type)) +
geom_boxplot(alpha = 0.7) +   geom_jitter(width = 0.2, alpha = 0.2) +
  theme_minimal() +
  labs(title = "Distribution of Scores with Data Points", y = "Score Value", x = "") +
theme(legend.position = "none")

# Arrange multiple plots in a grid
grid.arrange(scatter_plot, residual_plot, density_plot, diff_plot, qq_plot, box_plot, ncol = 2)

# Compute correlation matrix
cor_data <- data %>% select(Score, WPCS_Score) cor_matrix
<- cor(cor_data)

# Correlation heatmap
correlation_heatmap <- ggplot(data = as.data.frame(as.table(cor_matrix)), aes(x = Var1, y = Var2, fill =
Freq)) +   geom_tile() +
  geom_text(aes(label = round(Freq, 3)), color = "white") +
  scale_fill_gradient2(low = "blue", high = "red", mid = "white", midpoint = 0, limit = c(-1, 1), name =
"Correlation")                              +
theme_minimal() +
  labs(title = "Correlation Heatmap", x = "", y = "")

print(correlation_heatmap)

# Bland-Altman plot
data$mean_score <- (data$Score + data$WPCS_Score) / 2
data$diff_score <- data$WPCS_Score - data$Score
mean_diff <- mean(data$diff_score) sd_diff <-
sd(data$diff_score) upper_limit <- mean_diff + 1.96 *
sd_diff lower_limit <- mean_diff - 1.96 * sd_diff

bland_altman_plot <- ggplot(data, aes(x = mean_score, y = diff_score)) +
geom_point(alpha = 0.6, color = "blue") +   geom_hline(yintercept =
mean_diff, color = "red") +
  geom_hline(yintercept = upper_limit, color = "red", linetype = "dashed") +
geom_hline(yintercept = lower_limit, color = "red", linetype = "dashed") +   theme_minimal()
+
  labs(
    title = "Bland-Altman Plot: Agreement between Score and WPCS_Score",
x = "Mean of Scores",
    y = "Difference (WPCS - Original)",
    subtitle = paste("Mean diff:", round(mean_diff, 3), "| 95% Limits of Agreement:", round(lower_limit,
3), "to", round(upper_limit, 3))
  )
print(bland_altman_plot) #
Print error metrics
cat("\nOverall Error Metrics:\n")
cat("RMSE:", rmse_val, "\n") cat("MAE:",
```

```
mae_val, "\n") cat("Correlation:",
correlation, "\n") cat("R-squared:",
r_squared, "\n")
```

```
print(bland_altman_plot)
```



Error:

```
if (!require("ggplot2")) install.packages("ggplot2", dependencies = TRUE)  if
(!require("Metrics")) install.packages("Metrics", dependencies = TRUE) if
(!require("gridExtra")) install.packages("gridExtra", dependencies = TRUE)

library(ggplot2) library(Metrics)
library(gridExtra)

# Load dataset
data <- read.csv("C:/Users/shire/OneDrive/Desktop/novel_score_comparison.csv")

# Calculate error metrics rmse_val <-
rmse(data$Score, data$WPCS_Score)  mae_val <-
mae(data$Score, data$WPCS_Score)  mape_val <-
mape(data$Score, data$WPCS_Score)  correlation
<- cor(data$Score, data$WPCS_Score)  r_squared
<- correlation^2

# Compute errors
data$error <- data$WPCS_Score - data$Score
data$error_percentage <- ifelse(data$Score != 0, (abs(data$error) / data$Score) * 100, NA)
data$absolute_error <- abs(data$error)

# Create score buckets
score_range <- max(data$Score) - min(data$Score)  break_size
<- score_range / 5
breaks <- seq(min(data$Score), max(data$Score), length.out = 6)
data$score_bucket <- cut(data$Score, breaks = breaks, labels = c("Lowest 20%", "20-40%", "40-60%", "60-
80%", "Highest 20%"), include.lowest = TRUE)

# Scatter plot
scatter_plot <- ggplot(data, aes(x = Score, y = WPCS_Score)) +
geom_point(alpha = 0.6, color = "blue") +    geom_smooth(method
= "lm", color = "red") +
  geom_abline(slope = 1, intercept = 0, linetype = "dashed", color = "gray") +
theme_minimal() +
  labs(title = "Score vs WPCS_Score Comparison", x = "Original Score", y = "WPCS Score",
subtitle = paste("Correlation:", round(correlation, 3), "| RMSE:", round(rmse_val, 3), "| R²:",
round(r_squared, 3)))

# Residual plot
residual_plot <- ggplot(data, aes(x = Score, y = error)) +
geom_point(alpha = 0.6, color = "blue") +
  geom_hline(yintercept = 0, linetype = "dashed", color = "red") +
theme_minimal() +
  labs(title = "Residual Plot", x = "Original Score", y = "Difference (WPCS - Original)")
# Error Percentage by Score Range
bucket_error_plot <- ggplot(data, aes(x = score_bucket, y = error_percentage)) +
geom_boxplot(fill = "lightblue") +   theme_minimal() +
  labs(title = "Error Percentage by Score Range", x = "Score Range", y = "Error Percentage (%)")
# Error Distribution
error_dist_plot <- ggplot(data, aes(x = error)) +
geom_histogram(bins = 30, fill = "blue", alpha = 0.6) +
```

```
geom_vline(xintercept = 0, color = "red", linetype = "dashed") +
theme_minimal() +
  labs(title = "Distribution of Score Differences", x = "Difference (WPCS - Original)", y = "Count")
```

```r
# Score Distributions
combined_data <- data.frame(Value = c(data$Score, data$WPCS_Score), Type = rep(c("Original
Score", "WPCS Score"), each = nrow(data)))

density_plot <- ggplot(combined_data, aes(x = Value, fill = Type)) +
geom_density(alpha = 0.5) +
  geom_vline(data = data.frame(Type = c("Original Score", "WPCS Score"), mean_val =
c(mean(data$Score), mean(data$WPCS_Score))),
             aes(xintercept = mean_val, color = Type), linetype = "dashed") +    theme_minimal()
+
  labs(title = "Score Distributions with Mean Lines", x = "Score Value", y = "Density")

# Box Plot
box_plot <- ggplot(combined_data, aes(x = Type, y = Value, fill = Type)) +
geom_boxplot(alpha = 0.7) +   theme_minimal() +
  labs(title = "Distribution of Scores", y = "Score Value", x = "") +
theme(legend.position = "none")

# Correlation by Score Bucket
correlation_by_bucket <- data.frame(score_bucket = levels(data$score_bucket), correlation =
numeric(length(levels(data$score_bucket))))

for (i in 1:length(levels(data$score_bucket))) {
  bucket_data <- data[data$score_bucket == levels(data$score_bucket)[i], ]   if
(length(unique(bucket_data$Score)) > 1) {
    correlation_by_bucket$correlation[i] <- cor(bucket_data$Score, bucket_data$WPCS_Score)
  } else {
    correlation_by_bucket$correlation[i] <- NA
  }
}

corr_bucket_plot <- ggplot(correlation_by_bucket, aes(x = score_bucket, y = correlation)) +
geom_bar(stat = "identity", fill = "purple", alpha = 0.7) +
  geom_hline(yintercept = correlation, linetype = "dashed", color = "red") +
theme_minimal() +
  labs(title = "Correlation by Score Range", subtitle = paste("Overall correlation:", round(correlation,
3)), x = "Score Range", y = "Correlation") +
ylim(0, 1)

# Absolute Error Plot
abs_error_plot <- ggplot(data, aes(x = Score, y = absolute_error)) +    geom_point(alpha
= 0.6) +
  geom_smooth(method = "loess", color = "red") +
theme_minimal() +
  labs(title = "Absolute Error vs Original Score", x = "Original Score", y = "Absolute Error")

# Arrange plots
grid.arrange(scatter_plot, residual_plot, bucket_error_plot, error_dist_plot, density_plot, box_plot,
corr_bucket_plot, abs_error_plot, ncol = 2, nrow = 4)
```

```
# Print error metrics cat("\nOverall
Error Metrics:\n")  cat("RMSE:",
rmse_val, "\n") cat("MAE:",
mae_val, "\n") cat("MAPE:",
mape_val, "\n")  cat("Correlation:",
correlation, "\n")  cat("R-squared:",
r_squared, "\n")
```

```
Overall Error Metrics:
> cat("RMSE:", rmse_val, "\n")
RMSE: 0.01806435
> cat("MAE:", mae_val, "\n")
MAE: 0.001074939
> cat("MAPE:", mape_val, "\n")
MAPE: NaN
> cat("Correlation:", correlation, "\n")
Correlation: 0.999869
> cat("R-squared:", r_squared, "\n")
R-squared: 0.9997379
Summary Statistics:
> print(summary_stats)
              Metric Original_Score WPCS_Score
1               Mean       4.179310   4.180385
2             Median       4.625000   4.750000
3 Standard Deviation       1.113772   1.113176
4                Min       0.000000   0.000000
5                Max       5.000000   5.000000
6                IQR       1.500000   1.500000
>
```

```
Error Statistics:
> print(error_stats)
                     Metric       Value
1              Mean Error %  0.03501105
2            Median Error %  0.00000000
3   90th Percentile Error %  0.00000000
4   95th Percentile Error %  0.00000000
5               Max Error % 14.28571429
6   % Cases with Error < 5% 99.62779156
7  % Cases with Error < 10% 99.83457403
8 Number of NA/Invalid Cases 24.00000000
>
> cat("\nError Analysis by Score Range:\n")

Error Analysis by Score Range:
> print(error_by_range)
  score_bucket error_percentage.mean error_percentage.median error_percentage.sd
1   Lowest 20%            0.00000000              0.00000000          0.00000000
2       20-40%            0.10131712              0.00000000          1.20307417
3       40-60%            0.07432181              0.00000000          0.90720824
4       60-80%            0.05938414              0.00000000          0.70993719
5  Highest 20%            0.01526366              0.00000000          0.35425035
  error_percentage.na_count
1                0.00000000
2                0.00000000
3                0.00000000
4                0.00000000
5                0.00000000
>
> cat("\nCorrelation by Score Range:\n")

Correlation by Score Range:
> print(correlation_by_bucket)
  score_bucket correlation
1   Lowest 20%   1.0000000
2       20-40%   0.9960345
3       40-60%   0.9967120
4       60-80%   0.9948897
5  Highest 20%   0.9973036
```

Comparison between method 1 and 2:

```
# Load necessary libraries

library(tidyverse)

library(caret)

library(ggplot2)

library(car)

library(gridExtra)


# Set seed for reproducibility

set.seed(123)

# Define Skewness and Kurtosis

Functions skewness <- function(x) {   n

<- length(x)   m <- mean(x)   s <- sd(x)

sum((x - m)^3) / (n * s^3)

} kurtosis <-

function(x) {   n <-

length(x)   m <-

mean(x)   s <- sd(x)

  (sum((x - m)^4) / (n * s^4)) - 3

}

# Define Safe Mean Absolute Percentage Error

Function safe_mape <- function(actual, predicted) {

valid_indices <- which(actual != 0)   if

(length(valid_indices) == 0) return(NA)   actual_valid

<- actual[valid_indices]   predicted_valid <-

predicted[valid_indices]

  return(mean(abs((actual_valid - predicted_valid) / actual_valid)) * 100)

}

# Define Bland-Altman Analysis Function

calculate_bland_altman <- function(original, derived, name)
{   diff <- original - derived   mean_vals <- (original +
derived) / 2   mean_diff <- mean(diff)   sd_diff <- sd(diff)
```

```
  lower_limit <- mean_diff - 1.96 * sd_diff
upper_limit <- mean_diff + 1.96 * sd_diff
return(data.frame(
    Dataset = name,
    Mean_Difference = mean_diff,
    SD_Difference = sd_diff,
    Lower_Limit = lower_limit,
    Upper_Limit = upper_limit,
    Percentage_Within_Limits = mean(diff >= lower_limit & diff <= upper_limit) * 100
  ))
}
# Load Datasets wpcs_data <-
read.csv("C:/Users/shire/OneDrive/Desktop/novel_score_comparison.csv") mutated_data
<- read.csv("C:/Users/shire/OneDrive/Desktop/mutated_key_with_scores.csv")
# Initialize Results List
results <- list()
# Summary Statistics results$dataset1_summary <-
summary(wpcs_data) results$dataset2_summary <-
summary(mutated_data) # Descriptive Statistics for
WPCS_Score and New_Score wpcs_stats <-
data.frame(   Dataset = "WPCS_Score",
  Mean_Original = mean(wpcs_data$Score),
  Mean_Derived = mean(wpcs_data$WPCS_Score),
  Median_Original = median(wpcs_data$Score),
  Median_Derived = median(wpcs_data$WPCS_Score),
  SD_Original = sd(wpcs_data$Score),
  SD_Derived = sd(wpcs_data$WPCS_Score),
  Min_Original = min(wpcs_data$Score),
  Min_Derived = min(wpcs_data$WPCS_Score),
  Max_Original = max(wpcs_data$Score),
  Max_Derived = max(wpcs_data$WPCS_Score),
  Skewness_Original = skewness(wpcs_data$Score),
  Skewness_Derived = skewness(wpcs_data$WPCS_Score),
  Kurtosis_Original = kurtosis(wpcs_data$Score),
  Kurtosis_Derived = kurtosis(wpcs_data$WPCS_Score)
)
```

```
new_stats <- data.frame(
Dataset = "New_Score",
  Mean_Original = mean(mutated_data$Score),
  Mean_Derived = mean(mutated_data$New_Score),
  Median_Original = median(mutated_data$Score),
  Median_Derived = median(mutated_data$New_Score),
  SD_Original = sd(mutated_data$Score),
  SD_Derived = sd(mutated_data$New_Score),
  Min_Original = min(mutated_data$Score),
  Min_Derived = min(mutated_data$New_Score),
  Max_Original = max(mutated_data$Score),
  Max_Derived = max(mutated_data$New_Score),
  Skewness_Original = skewness(mutated_data$Score),
  Skewness_Derived = skewness(mutated_data$New_Score),
  Kurtosis_Original = kurtosis(mutated_data$Score),
  Kurtosis_Derived = kurtosis(mutated_data$New_Score)
)

results$all_stats <- rbind(wpcs_stats, new_stats)

# Error Metrics Calculation
wpcs_metrics <- data.frame(
  Dataset = "WPCS_Score",
  MSE = mean((wpcs_data$Score - wpcs_data$WPCS_Score)^2),
  RMSE = sqrt(mean((wpcs_data$Score - wpcs_data$WPCS_Score)^2)),
  MAE = mean(abs(wpcs_data$Score - wpcs_data$WPCS_Score)),
  MAPE = safe_mape(wpcs_data$Score, wpcs_data$WPCS_Score),
  R_squared = cor(wpcs_data$Score, wpcs_data$WPCS_Score)^2
)
new_metrics <- data.frame(
  Dataset = "New_Score",
  MSE = mean((mutated_data$Score - mutated_data$New_Score)^2),
  RMSE = sqrt(mean((mutated_data$Score - mutated_data$New_Score)^2)),
  MAE = mean(abs(mutated_data$Score - mutated_data$New_Score)),
  MAPE = safe_mape(mutated_data$Score, mutated_data$New_Score),
  R_squared = cor(mutated_data$Score, mutated_data$New_Score)^2
```

```
)

results$all_metrics <- rbind(wpcs_metrics, new_metrics)

# Statistical Tests results$wpcs_correlation <- cor.test(wpcs_data$Score,
wpcs_data$WPCS_Score) results$new_correlation <-
cor.test(mutated_data$Score, mutated_data$New_Score)

results$wpcs_ttest <- t.test(wpcs_data$Score, wpcs_data$WPCS_Score, paired = TRUE)
results$new_ttest <- t.test(mutated_data$Score, mutated_data$New_Score, paired = TRUE)

results$wpcs_wilcox <- wilcox.test(wpcs_data$Score, wpcs_data$WPCS_Score, paired = TRUE)
results$new_wilcox <- wilcox.test(mutated_data$Score, mutated_data$New_Score, paired =
TRUE)

# Kolmogorov-Smirnov Test results$ks_wpcs <-
ks.test(wpcs_data$Score, wpcs_data$WPCS_Score) results$ks_new <-
ks.test(mutated_data$Score, mutated_data$New_Score)

# Bland-Altman Analysis results$wpcs_ba <-
calculate_bland_altman(wpcs_data$Score, wpcs_data$WPCS_Score,
"WPCS_Score") results$new_ba <- calculate_bland_altman(mutated_data$Score,
mutated_data$New_Score, "New_Score")

results$bland_altman_results <- rbind(results$wpcs_ba, results$new_ba)

# Print Results
print("-------- ANALYSIS RESULTS --------
") print(results$dataset1_summary)
print(results$dataset2_summary) print("------
-- Descriptive Statistics --------")
print(results$all_stats) print("-------- Error
Metrics --------") print(results$all_metrics)
print("-------- Correlation Analysis --------
") print(results$wpcs_correlation)
print(results$new_correlation) print("------
```

```
-- Paired t-tests --------")
print(results$wpcs_ttest)
print(results$new_ttest) print("--------
Wilcoxon Signed Rank Test --------")
print(results$wpcs_wilcox)
print(results$new_wilcox) print("--------
Kolmogorov-Smirnov Test --------")
print(results$ks_wpcs)
print(results$ks_new) print("-------- Bland-
Altman Analysis --------")
print(results$bland_altman_results)

# Print Author Details
cat("NAME: Shirehya KP\n")
cat("REGNO: 22BDS0365\n")
```

```
> print("-------- ANALYSIS RESULTS --------")
[1] "-------- ANALYSIS RESULTS --------"
> print("Dataset 1: WPCS_Score")
[1] "Dataset 1: WPCS_Score"
> print(results$dataset1_summary)
     number         Questions            Answers             Texts               Score      
 Min.   : 1.100   Length:2442        Length:2442        Length:2442        Min.   :0.000  
 1st Qu.: 3.700   Class :character   Class :character   Class :character   1st Qu.:3.500  
 Median : 7.400   Mode  :character   Mode  :character   Mode  :character   Median :4.625  
 Mean   : 7.202                                                            Mean   :4.179  
 3rd Qu.:10.600                                                            3rd Qu.:5.000  
 Max.   :12.900                                                            Max.   :5.000  
 Answer_Keywords     Text_Keywords      New_Answer_Keywords Combined_Answer_Keywords
 Length:2442        Length:2442        Length:2442         Length:2442             
 Class :character   Class :character   Class :character    Class :character        
 Mode  :character   Mode  :character   Mode  :character    Mode  :character        



   WPCS_Score  
 Min.   :0.00  
 1st Qu.:3.50  
 Median :4.75  
 Mean   :4.18  
 3rd Qu.:5.00  
 Max.   :5.00  
> 
> print("Dataset 2: New_Score")
[1] "Dataset 2: New_Score"
> print(results$dataset2_summary)
     number         Questions            Answers             Texts               Score      
 Min.   : 1.100   Length:2442        Length:2442        Length:2442        Min.   :0.000  
 1st Qu.: 3.700   Class :character   Class :character   Class :character   1st Qu.:3.500  
 Median : 7.400   Mode  :character   Mode  :character   Mode  :character   Median :4.625  
 Mean   : 7.202                                                            Mean   :4.179  
 3rd Qu.:10.600                                                            3rd Qu.:5.000  
 Max.   :12.900                                                            Max.   :5.000  
 Answer_Keywords     Text_Keywords      New_Answer_Keywords Combined_Answer_Keywords
 Length:2442        Length:2442        Length:2442         Length:2442             
 Class :character   Class :character   Class :character    Class :character        
 Mode  :character   Mode  :character   Mode  :character    Mode  :character        



 Cosine_Similarity Euclidean_Distance Manhattan_Distance Pearson_Correlation Norm_Euclidean  
 Min.   :0.0000    Min.   :0.000      Min.   : 0.00      Min.   :-0.005133   Min.   :0.1089  
 1st Qu.:0.1021    1st Qu.:2.449      1st Qu.: 6.00      1st Qu.: 0.098913   1st Qu.:0.2000  
 Median :0.2582    Median :3.317      Median :11.00      Median : 0.255671   Median :0.2317  
 Mean   :0.3054    Mean   :3.129      Mean   :11.34      Mean   : 0.303540   Mean   :0.2890  
 3rd Qu.:0.4364    3rd Qu.:4.000      3rd Qu.:16.00      3rd Qu.: 0.434694   3rd Qu.:0.2899  
 Max.   :1.0000    Max.   :8.185      Max.   :67.00      Max.   : 1.000000   Max.   :1.0000  
 Norm_Manhattan    Adjusted_Pearson Combined_Similarity   New_Score    
 Min.   :0.01471   Min.   :0.4974   Min.   :0.08203     Min.   :0.000  
 Min.   :0.01471   Min.   :0.4974   Min.   :0.08203     Min.   :0.000  
 1st Qu.:0.05882   1st Qu.:0.5495   1st Qu.:0.16400     1st Qu.:4.000  
 Median :0.08333   Median :0.6278   Median :0.24958     Median :4.500  
 Mean   :0.16002   Mean   :0.6518   Mean   :0.30765     Mean   :4.136  
 3rd Qu.:0.14286   3rd Qu.:0.7173   3rd Qu.:0.36255     3rd Qu.:5.000  
 Max.   :1.00000   Max.   :1.0000   Max.   :1.00000     Max.   :5.000  
> 
> print("-------- Descriptive Statistics --------")
[1] "-------- Descriptive Statistics --------"
> print(results$all_stats)
     Dataset Mean_Original Mean_Derived Median_Original Median_Derived SD_Original SD_Derived
1 WPCS_Score       4.17931     4.180385           4.625           4.75    1.113772   1.113176
2  New_Score       4.17931     4.136364           4.625           4.50    1.113772   1.120658
  Min_Original Min_Derived Max_Original Max_Derived Skewness_Original Skewness_Derived
1            0           0            5           5         -1.420269        -1.422468
2            0           0            5           5         -1.420269        -1.373131
  Kurtosis_Original Kurtosis_Derived
1          1.454908         1.463451
2          1.454908         1.340636
> 
> print("-------- Error Metrics --------")
[1] "-------- Error Metrics --------"
> print(results$all_metrics)
     Dataset          MSE       RMSE         MAE       MAPE R_squared
1 WPCS_Score 0.0003263206 0.01806435 0.001074939 0.03501105 0.9997379
2  New_Score 0.0694295147 0.26349481 0.139281327 4.38962895 0.9466005
> 
> print("-------- Correlation Analysis --------")
[1] "-------- Correlation Analysis --------"
> print("WPCS_Score Correlation with Score:")
[1] "WPCS_Score Correlation with Score:"
> print(results$wpcs_correlation)

	Pearson's product-moment correlation

data:  wpcs_data$Score and wpcs_data$WPCS_Score
t = 3050.9, df = 2440, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.9998581 0.9998790
sample estimates:
     cor 
0.999869 

> 
> print("New_Score Correlation with Score:")
[1] "New_Score Correlation with Score:"
> print(results$new_correlation)

	Pearson's product-moment correlation

data:  mutated_data$Score and mutated_data$New_Score
t = 207.97, df = 2440, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.9707308 0.9749734
sample estimates:
     cor 
0.972934 

> 
> print("-------- Paired t-tests --------")
[1] "-------- Paired t-tests --------"
> print("WPCS_Score vs Score (Paired t-test):")
[1] "WPCS_Score vs Score (Paired t-test):"
> print(results$wpcs_ttest)

	Paired t-test

data:  wpcs_data$Score and wpcs_data$WPCS_Score
t = -2.9452, df = 2441, p-value = 0.003258
alternative hypothesis: true mean difference is not equal to 0
95 percent confidence interval:
 -0.0017906395 -0.0003592376
sample estimates:
mean difference 
   -0.001074939 
```

```
> print("New_Score vs Score (Paired t-test):")
[1] "New_Score vs Score (Paired t-test):"
> print(results$new_ttest)

        Paired t-test

data:  mutated_data$Score and mutated_data$New_Score
t = 8.1618, df = 2441, p-value = 5.228e-16
alternative hypothesis: true mean difference is not equal to 0
95 percent confidence interval:
 0.03262813 0.05326458
sample estimates:
mean difference
     0.04294636

>
> print("-------- Wilcoxon Signed Rank Test --------")
[1] "-------- Wilcoxon Signed Rank Test --------"
> print("WPCS_Score vs Score (Wilcoxon test):")
[1] "WPCS_Score vs Score (Wilcoxon test):"
> print(results$wpcs_wilcox)

        Wilcoxon signed rank test with continuity correction

data:  wpcs_data$Score and wpcs_data$WPCS_Score
V = 0, p-value = 0.006927
alternative hypothesis: true location shift is not equal to 0
> print("New_Score vs Score (Wilcoxon test):")
[1] "New_Score vs Score (Wilcoxon test):"
> print(results$new_wilcox)

        Wilcoxon signed rank test with continuity correction

data:  mutated_data$Score and mutated_data$New_Score
V = 153962, p-value = 6.685e-16
alternative hypothesis: true location shift is not equal to 0

>
> print("-------- Linear Regression Analysis --------")
[1] "-------- Linear Regression Analysis --------"
> print("WPCS_Score Regression Model:")
[1] "WPCS_Score Regression Model:"
> print(results$wpcs_lm_summary)

Call:
lm(formula = WPCS_Score ~ Score, data = wpcs_data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.00386 -0.00153 -0.00053 -0.00053  0.37389

Coefficients:
             Estimate Std. Error  t value Pr(>|t|)
(Intercept) 0.0038596  0.0014167    2.724  0.00649 **
Score       0.9993337  0.0003276 3050.905  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.01802 on 2440 degrees of freedom
Multiple R-squared:  0.9997,    Adjusted R-squared:  0.9997
F-statistic: 9.308e+06 on 1 and 2440 DF,  p-value: < 2.2e-16

> print(results$wpcs_lm_confint)
                  2.5 %      97.5 %
(Intercept) 0.001081526 0.006637662
Score       0.998691394 0.999976016
>
> print("New_Score Regression Model:")
[1] "New_Score Regression Model:"
> print(results$new_lm_summary)

Call:
lm(formula = New_Score ~ Score, data = mutated_data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.53451  0.01812  0.06022  0.06022  0.52865

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.045030   0.020359   2.212   0.0271 *
Score       0.978949   0.004707 207.974   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.259 on 2440 degrees of freedom
Multiple R-squared:  0.9466,    Adjusted R-squared:  0.9466
F-statistic: 4.325e+04 on 1 and 2440 DF,  p-value: < 2.2e-16

> print(results$new_lm_confint)
                  2.5 %     97.5 %
(Intercept) 0.005108478 0.08495239
Score       0.969719180 0.98817971
>
> print("-------- Distribution Similarity Tests --------")
[1] "-------- Distribution Similarity Tests --------"
> print("Kolmogorov-Smirnov Test - WPCS_Score vs Score:")
[1] "Kolmogorov-Smirnov Test - WPCS_Score vs Score:"
> print(results$ks_wpcs)

        Asymptotic two-sample Kolmogorov-Smirnov test

data:  wpcs_data$Score and wpcs_data$WPCS_Score
D = 0.000819, p-value = 1
alternative hypothesis: two-sided

>
> print("Kolmogorov-Smirnov Test - New_Score vs Score:")
[1] "Kolmogorov-Smirnov Test - New_Score vs Score:"
> print(results$ks_new)

        Asymptotic two-sample Kolmogorov-Smirnov test

data:  mutated_data$Score and mutated_data$New_Score
D = 0.12899, p-value < 2.2e-16
alternative hypothesis: two-sided

>
> print("-------- Bland-Altman Analysis --------")
[1] "-------- Bland-Altman Analysis --------"
> print(results$bland_altman_results)
     Dataset Mean_Difference SD_Difference Lower_Limit Upper_Limit Percentage_Within_Limits
1 WPCS_Score    -0.001074939    0.01803603 -0.03642556  0.03427568                 99.63145
2  New_Score     0.042946355    0.26002464 -0.46670194  0.55259465                 90.45864
>
> print("-------- COMPREHENSIVE SUMMARY --------")
[1] "-------- COMPREHENSIVE SUMMARY --------"
> print("1. Which derived score is closer to the original score?")
[1] "1. Which derived score is closer to the original score?"
> print(results$comprehensive_summary$rmse_comparison)
[1] "WPCS_Score is closer to the original Score (lower RMSE)"
>
> print("2. Which derived score has stronger correlation with the original score?")
```

```
[1] "WPCS_Score: RMSE = 0.0180643471739401 MAE = 0.00107493857493857"
> print(results$comprehensive_summary$new_metrics)
[1] "New_Score: RMSE = 0.263494809706026 MAE = 0.139281326781327"
>
> if(!is.na(results$all_metrics$MAPE[1]) && !is.na(results$all_metrics$MAPE[2])) {
+   print(results$comprehensive_summary$wpcs_mape)
+   print(results$comprehensive_summary$new_mape)
+ } else {
+   print(results$comprehensive_summary$mape_status)
+ }
[1] "WPCS_Score MAPE = 0.0350110481925859 %"
[1] "New_Score MAPE = 4.38962895119759 %"
>
> print("4. Statistical significance of differences:")
[1] "4. Statistical significance of differences:"
> print(results$comprehensive_summary$wpcs_ttest_pvalue)
[1] "WPCS_Score p-value (t-test): 0.00325792178333613"
> print(results$comprehensive_summary$new_ttest_pvalue)
[1] "New_Score p-value (t-test): 5.22825061124778e-16"
> print(results$comprehensive_summary$wpcs_significance)
[1] "WPCS_Score is significantly different from the original Score"
> print(results$comprehensive_summary$new_significance)
[1] "New_Score is significantly different from the original Score"
>
> print("5. Regression model quality:")
[1] "5. Regression model quality:"
> print(results$comprehensive_summary$wpcs_r2)
[1] "WPCS_Score R²: 0.999737929285073 Adjusted R²: 0.999737821879042"
> print(results$comprehensive_summary$new_r2)
[1] "New_Score R²: 0.946600481955422 Adjusted R²: 0.946578596907043"
>
> print("6. Bland-Altman agreement:")
[1] "6. Bland-Altman agreement:"
> print(results$comprehensive_summary$wpcs_ba)
[1] "WPCS_Score mean difference: -0.00107493857493857 95% limits of agreement: -0.0364255561540002 to 0.034275679004123"
> print(results$comprehensive_summary$new_ba)
[1] "New_Score mean difference: 0.0429463554463554 95% limits of agreement: -0.466701936553918 to 0.552594647446628"
>
> print("7. Distribution similarity (KS test):")
[1] "7. Distribution similarity (KS test):"
> print(results$comprehensive_summary$wpcs_ks)
[1] "WPCS_Score KS test p-value: 1"
> print(results$comprehensive_summary$new_ks)
[1] "New_Score KS test p-value: 0"
>
> print("8. FINAL CONCLUSION:")
[1] "8. FINAL CONCLUSION:"
> print(results$comprehensive_summary$final_conclusion)
[1] "WPCS_Score performed better overall in matching the original Score values."
> print(results$comprehensive_summary$wpcs_criteria)
[1] "WPCS_Score won on 7 out of 7 criteria."
> print(results$comprehensive_summary$new_criteria)
[1] "New_Score won on 0 out of 7 criteria."
> cat("NAME: M THIRUNARAYANAN\n")
NAME: M THIRUNARAYANAN
> cat("REGNO: 22BDS0342\n")
REGNO: 22BDS0342
```

Result:

Key Findings

1. **Overall Performance**: WPCS_Score consistently outperformed New_Score in matching the original Score values, winning on all 7 evaluation criteria.
2. **Accuracy Metrics**:
   - WPCS_Score: RMSE = 0.018, MAE = 0.001, MAPE = 0.035%
   - New_Score: RMSE = 0.263, MAE = 0.139, MAPE = 4.390%
3. **Correlation with Original Score**:
   - WPCS_Score: $R^2 = 0.9997$ (extremely strong correlation)
   - New_Score: $R^2 = 0.9466$ (strong but lower correlation)
4. **Statistical Significance**:
   - Both derived scores showed statistically significant differences from the original Score ($p < 0.05$)
   - However, WPCS_Score's difference was much smaller (mean difference = -0.001)
   - New_Score had a larger deviation (mean difference = 0.043)
5. **Distribution Similarity**:
   - WPCS_Score: KS test p-value = 1 (distributions are identical)
   - New_Score: KS test p-value ≈ 0 (distributions are significantly different)
6. **Bland-Altman Agreement**:
   - WPCS_Score: 99.63% of values within limits of agreement
   - New_Score: 90.46% of values within limits of agreement

Descriptive Statistics Comparison

Both derived scores maintained similar central tendencies to the original Score:

- Original Score: Mean = 4.179, Median = 4.625
- WPCS_Score: Mean = 4.180, Median = 4.750
- New_Score: Mean = 4.136, Median = 4.500

Conclusion

WPCS_Score demonstrated superior performance in approximating the original Score across all evaluation metrics. While both methods produced scores with high correlation to the original, WPCS_Score showed near-perfect agreement with minimal error, making it the clearly preferred method for this application.