DUONUMERO: MULTILINGUALISM IN MATH

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ABSTRACT

In Northern Alaska, there is a town named Kaktovik where about 30 years ago middle school students and their teacher created a new numeral system. They named it after the town it was made in, and it's based on the Inuit language. My project is creating an app that teaches Kaktovik. I am using a programming language named SwiftUI to create an app that explains what Kaktovik is and how to use it then asks questions about Kaktovik. The students of Kaktovik learned both the Kaktovik numeral system and the Hindu-Arabic system, the most commonly used one today, and after one year they showed great improvements on standardized math test scores from below the 20th percentile to significantly above the national average. I assume learning another numeral system helps people learn math. My app is called DuoNumero and the current version has several features like buttons to click on the answers for the quizzes, arrows to move around the pages, random question generator, etc. A few testers found DuoNumero easy to understand and use. I also have extended the app to another numeral system by Mayan.
This is a project that combines math, software engineering, education, cultural studies, and arts.

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INTRODUCTION

In Northern Alaska, there is a small town called Kaktovik. In the early 1990s, 9 middle school students and their teacher in Kaktovik invented a new numeral system and named it after their town. The system is based on the Inuit language, and it is very visual, like tally marks. Due to it being visual, arithmetic is very simple. Even long division is intuitive. It is also similar to Roman Numerals. [1]

The region where Inuit language is spoken.

FIG 1. Inuit language is spoken in Northern Alaska, Canada, and Greenland; Kaktovik is a small town in Northern Alaska..

The Kaktovik system is base-20, meaning that instead of having 10 digits like 0-9, it has 20. (FIG 2.) One is a simple dash that turns into two with another dash creating a V shape. For 5, a stroke is turned around 90 degrees clockwise and put slightly above the digits 1-4. In that sense, the Kaktovik has a sub-base 5. The Kaktovik numeral system is 20 based because in Inuit language they use ten fingers and ten toes for counting.
The addition and subtraction are simply adding and taking away strokes.

A few years after its invention, the Kaktovik middle students were taught both the Kaktovik numeral system and the standard Hindu-Arabic system, the most commonly used system today, And the students leaped from below the 20th percentile to significantly higher than average in the standardized math tests. This demonstrated the effects of learning two numeral systems.

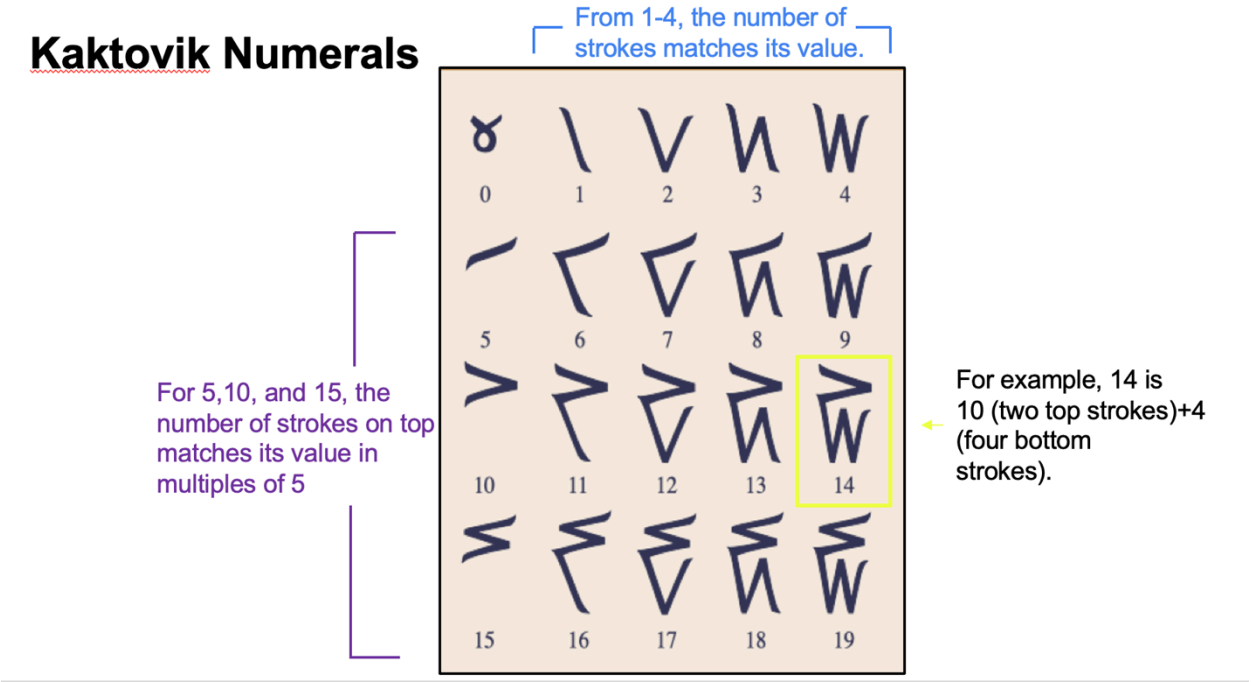


FIG. 2 The Kaktovik Numeral System is base-20.

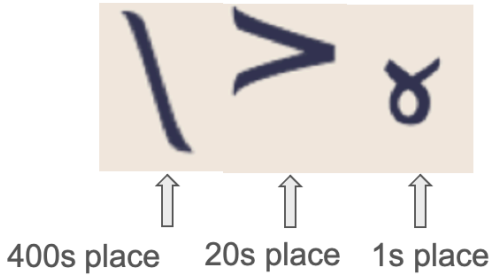

1x20 + 2x1 = 22


1x20 + 14x1 = 34

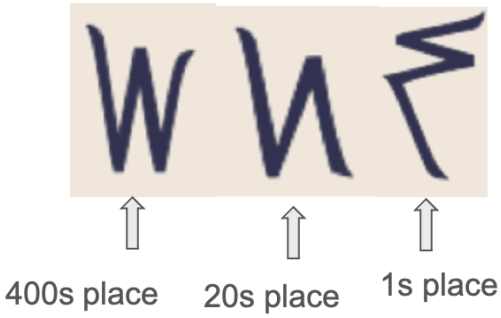

2x20 + 5x1 = 45


5x20 + 15x1 = 115

FIG. 2 Examples of the Kaktovik numbers

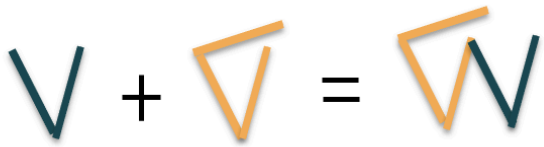


1x400 + 10x20 + 0x1 = 600

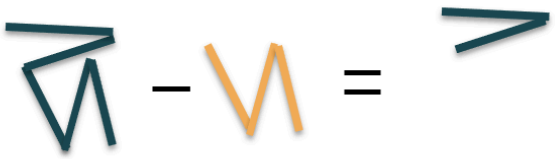


4x400 +3x20 + 16x1 = 476

FIG. 3 Three-digit numbers in Kaktovik



$2 + 7 = 9$



$13 - 3 = 10$

FIG. 4. Addition and subtraction are adding or removing strokes.

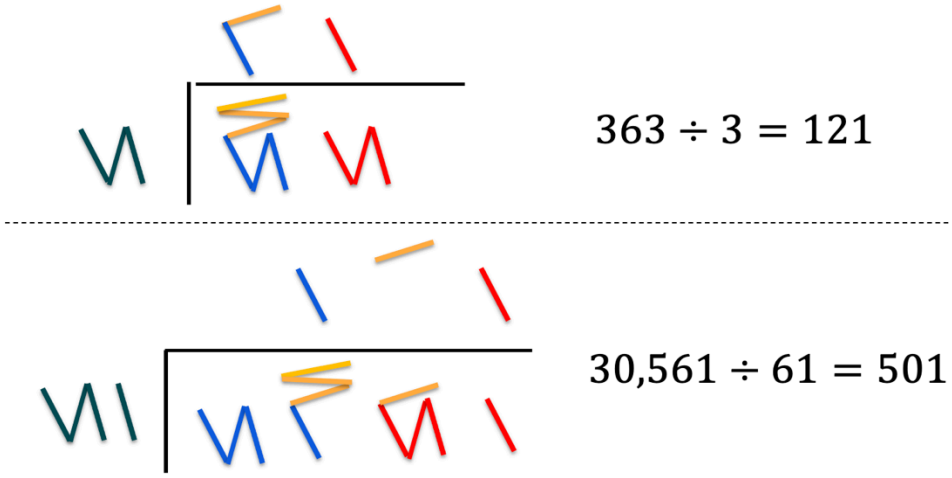


FIG. 5 Division is done by finding the same patterns.

The Kaktovik students had a few characteristics they wanted their numeral system to have and they are the following. [2]

- Visual Simplicity: The numbers are easy to remember
- Iconicity: The numerals have a clear relationship between the symbols and meaning
- Efficiency: They are easy to write quickly
- Distinctiveness: They are easily distinguishable from the Hindu-Arabic numerals

METHOD

The engineering goal of this project is to create an app called *DuoNumero* that teaches the Kaktovik Numeral system. The programming platform for creating an app is Xcode in mac ios and the programming language is Swift. I first downloaded Xcode and learned how to program in Swift by watching the tutorials on YouTube. I made the basic structure of DuoNumero as follows.

1) Home page
2) Introduction on Kaktovik
3) Lesson 1 and quizzes: addition
4) Lesson 2
5) Lesson 3
6) Lesson 4

Some of the features of DuoNumero are as follows.

1) The home page has the list of the contents. By clicking on the title of the topics, you can directly move to the corresponding page.
2) There are forward/backward arrows on each page for navigation.
3) The quizzes at the end of each lesson are selected randomly from a set of problems. Each time a user tries it, s/he will get a list of quizzes in a random order.

4) The quizzes are in a multiple-choice format and when the user clicks on an answer, it will tell you whether your answer was correct or not.

RESULTS

DuoNumero is working and is in its developmental stage. Currently, there is no published app to teach Kaktovik; it is the first app that teaches Kaktovik. All the features listed in the previous section are active. Here are some of the pages you can find in DuoNumero. (FIG. 6.) A few testers tried DuoNumero and they found it easy to use.

- The arrows are especially convenient when the user needs to review the previous contents and also when s/he wants to skip ahead.
- When the user clicks on an incorrect answer for a quiz, s/he can try again.

FIG. 6 Some pages in DuoNumero

DISCUSSION/CONCLUSION

As mentioned earlier, when the students in Kaktovik were taught both the Hindu-Arabic system and the Kaktovik system, their standardized test scores leaped from below the 20th percentile to significantly above the national average. This illustrates how learning math in a different numeral system can be beneficial. Research has shown that multilingualism in everyday language is related to brain development, higher academic performances, and cultural/social connections. [3,4] Learning another numeral system may help one understand their base numerals (like Hindu-Arabic) better. [3,4] It may also boost interest in math in general. Math is often regarded as abstract. But the cultural background of the Kaktovik and the story behind the invention of it is interesting. Nine middle school students and their teacher creating a completely new numeral system is incredibly inspiring as well. The intuitive nature of Kaktovik may allow for people to find math easier which can lead them to have a greater interest in it. Kaktovik is a great tool to use, especially if someone struggles in math. Multilingualism has its own benefits which is very likely similar to multilingualism in a mathematical sense.
DuoNumero is a tool that is easy to use to learn Kaktovik. A few test users tried DuoNumero and reported it is efficiently designed and easy to use.

In fact, Kaktovik is not the only indigenous numeral system. Mayan culture has a base-20 numeral system and Cherokee has their own as well. DuoNumero can have lessons in these in the future. Language is a central part of any culture. The numeric system unique to the associated language and people is an important way to understand them. DuoNumero is one tool to help such efforts.

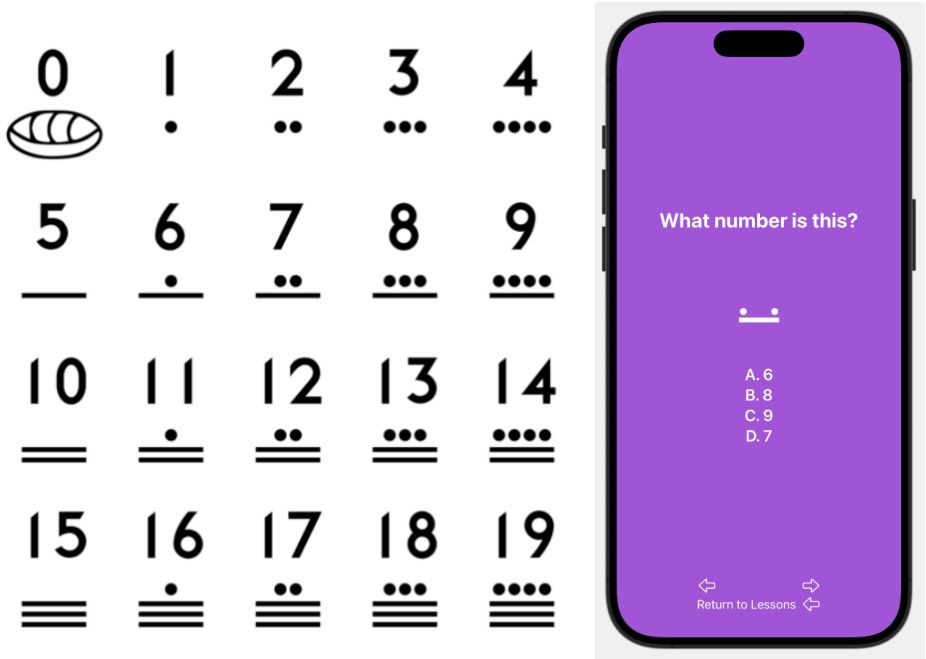


FIG. 7 The Mayab numeral system; an example of Mayan in DuoNumero

ACKNOWLEDGEMENTS

I thank my dad, Bradley Plohr, for helping me learn to use Xcode and spending many hours helping me write the code for DuoNumero. I also thank my mom, JeeYeon Plohr, for telling me about the Kaktovik Numeral system, and her perseverance to help me learn about Kaktovik and Xcode.

REFERENCES

[1] Tillinghast-Raby, A. (2024, February 20). *A number system invented by Inuit schoolchildren will make its Silicon Valley debut*. Scientific American. https://www.scientificamerican.com/article/a-number-system-invented-by-inuit-schoolchildren-will-make-its-silicon-valley-debut1/

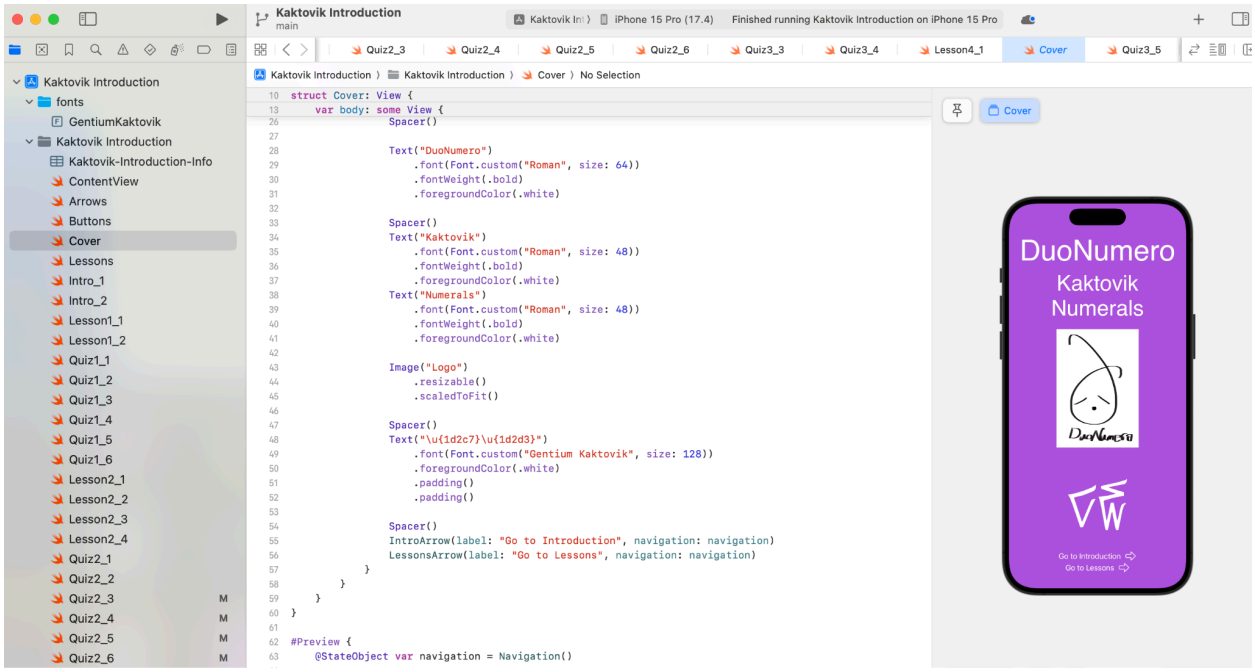
[2] Wikimedia Foundation. (2023, December 24). *Kaktovik numerals*. Wikipedia. https://en.wikipedia.org/wiki/Kaktovik_numerals

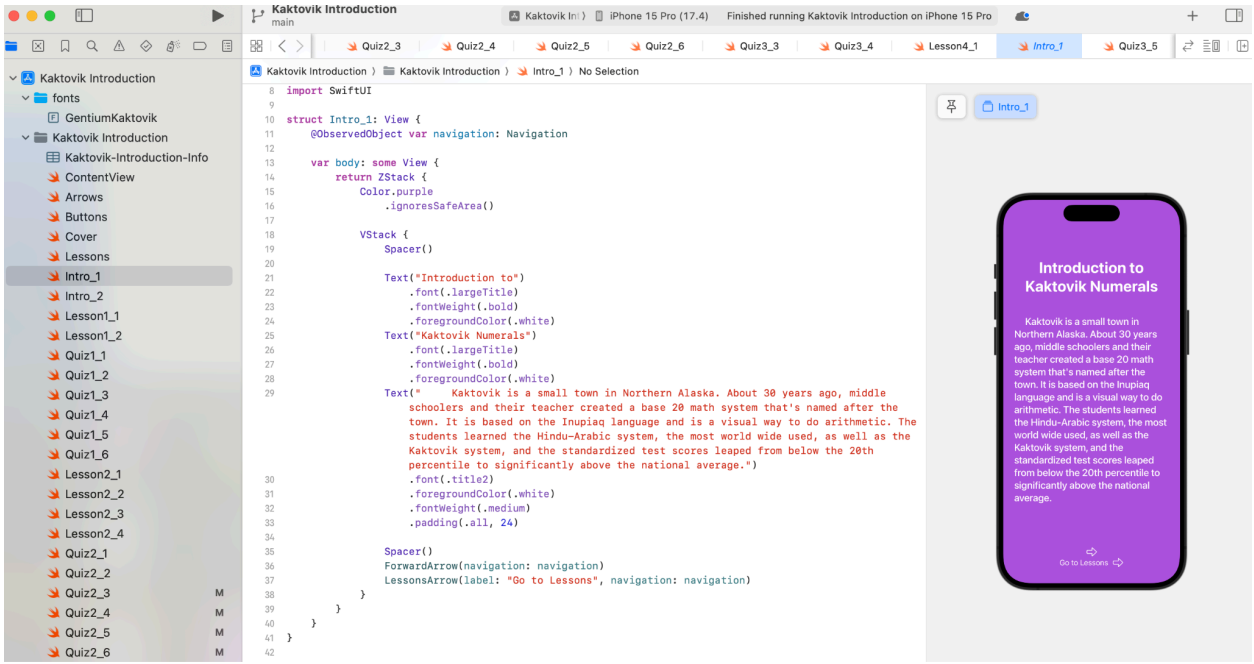
[3] Aftunion. (2023, July 18). *Bilingual education*. American Federation of Teachers. https://www.aft.org/ae/fall2015/goldenberg_wagner

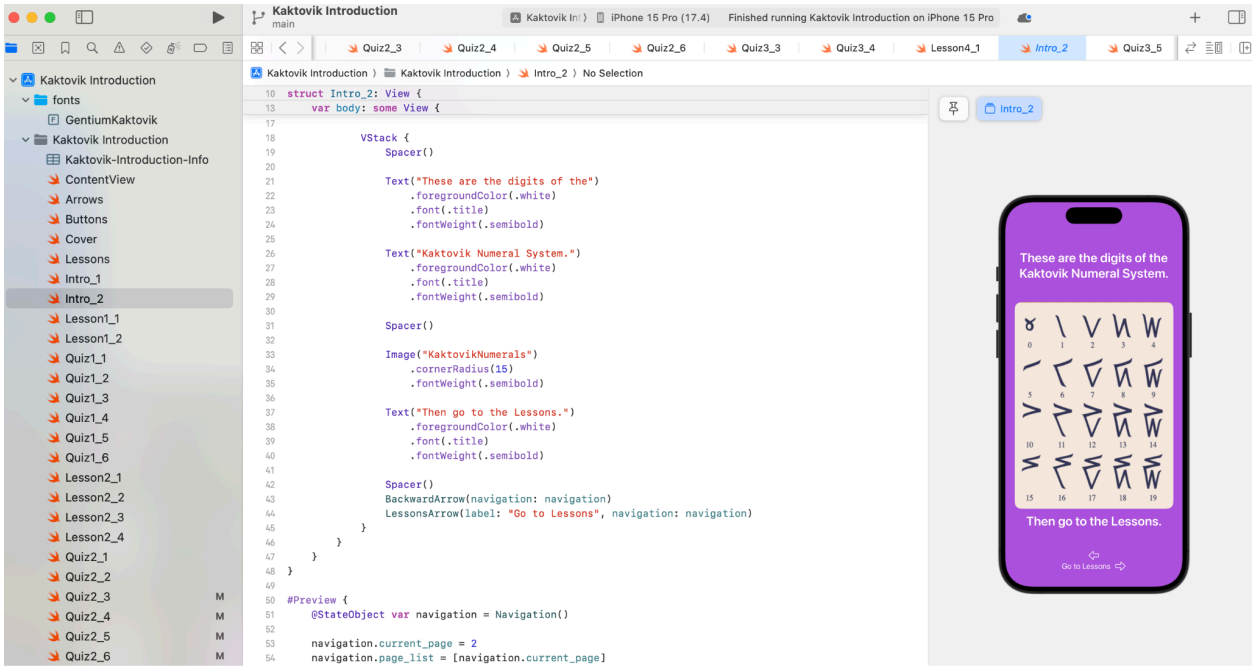
[4] The benefits of being bilingual (PDF). (n.d.-a). https://www2.ed.gov/documents/early-learning/talk-read-sing/bilingual-en.pd

APPENDIX

Here are samples of my code in SwiftUI with the simulator:


Kaktovik Introduction
main
iPhone 15 Pro (17.4)
Finished running Kaktovik Introduction on iPhone 15 Pro
Quiz2_3 Quiz2_4 Quiz2_5 Quiz2_6 Quiz3_3 Quiz3_4 Lesson4_1 Cover Quiz3_5
Kaktovik Introduction ⟩ Kaktovik Introduction ⟩ Cover ⟩ No Selection
Kaktovik Introduction
fonts
GentiumKaktovik
Kaktovik Introduction
Kaktovik-Introduction-Info
ContentView
Arrows
Buttons
Cover
Lessons
Intro_1
Intro_2
Lesson1_1
Lesson1_2
Quiz1_1
Quiz1_2
Quiz1_3
Quiz1_4
Quiz1_5
Quiz1_6
Lesson2_1
Lesson2_2
Lesson2_3
Lesson2_4
Quiz2_1
Quiz2_2
Quiz2_3 M
Quiz2_4 M
Quiz2_5 M
Quiz2_6 M
struct Cover: View {
var body: some View {
Spacer()
Text("DuoNumero")
.font(Font.custom("Roman", size: 64))
.fontWeight(.bold)
.foregroundColor(.white)
Spacer()
Text("Kaktovik")
.font(Font.custom("Roman", size: 48))
.fontWeight(.bold)
.foregroundColor(.white)
Text("Numerals")
.font(Font.custom("Roman", size: 48))
.fontWeight(.bold)
.foregroundColor(.white)
Image("Logo")
.resizable()
.scaledToFit()
Spacer()
Text("\u{1d2c7}\u{1d2d3}")
.font(Font.custom("Gentium Kaktovik", size: 128))
.foregroundColor(.white)
.padding()
.padding()
Spacer()
IntroArrow(label: "Go to Introduction", navigation: navigation)
LessonsArrow(label: "Go to Lessons", navigation: navigation)
}
}
}
}
#Preview {
@StateObject var navigation = Navigation()
Cover
DuoNumero
Kaktovik
Numerals
Go to Introduction
Go to Lessons


Kaktovik Introduction
main
iPhone 15 Pro (17.4)
Finished running Kaktovik Introduction on iPhone 15 Pro
Quiz2_3 Quiz2_4 Quiz2_5 Quiz2_6 Quiz3_3 Quiz3_4 Lesson4_1 Intro_1 Quiz3_5
Kaktovik Introduction ⟩ Kaktovik Introduction ⟩ Intro_1 ⟩ No Selection
Kaktovik Introduction
fonts
GentiumKaktovik
Kaktovik Introduction
Kaktovik-Introduction-Info
ContentView
Arrows
Buttons
Cover
Lessons
Intro_1
Intro_2
Lesson1_1
Lesson1_2
Quiz1_1
Quiz1_2
Quiz1_3
Quiz1_4
Quiz1_5
Quiz1_6
Lesson2_1
Lesson2_2
Lesson2_3
Lesson2_4
Quiz2_1
Quiz2_2
Quiz2_3 M
Quiz2_4 M
Quiz2_5 M
Quiz2_6 M
import SwiftUI
struct Intro_1: View {
@ObservedObject var navigation: Navigation
var body: some View {
return ZStack {
Color.purple
.ignoresSafeArea()
VStack {
Spacer()
Text("Introduction to")
.font(.largeTitle)
.fontWeight(.bold)
.foregroundColor(.white)
Text("Kaktovik Numerals")
.font(.largeTitle)
.fontWeight(.bold)
.foregroundColor(.white)
Text(" Kaktovik is a small town in Northern Alaska. About 30 years ago, middle schoolers and their teacher created a base 20 math system that's named after the town. It is based on the Inupiaq language and is a visual way to do arithmetic. The students learned the Hindu-Arabic system, the most world wide used, as well as the Kaktovik system, and the standardized test scores leaped from below the 20th percentile to significantly above the national average.")
.font(.title2)
.foregroundColor(.white)
.fontWeight(.medium)
.padding(.all, 24)
Spacer()
ForwardArrow(navigation: navigation)
LessonsArrow(label: "Go to Lessons", navigation: navigation)
}
}
}
}
Intro_1
Introduction to
Kaktovik Numerals
Kaktovik is a small town in Northern Alaska. About 30 years ago, middle schoolers and their teacher created a base 20 math system that's named after the town. It is based on the Inupiaq language and is a visual way to do arithmetic. The students learned the Hindu-Arabic system, the most world wide used, as well as the Kaktovik system, and the standardized test scores leaped from below the 20th percentile to significantly above the national average.
Go to Lessons


Kaktovik Introduction
main
iPhone 15 Pro (17.4)
Finished running Kaktovik Introduction on iPhone 15 Pro
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GentiumKaktovik
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ContentView
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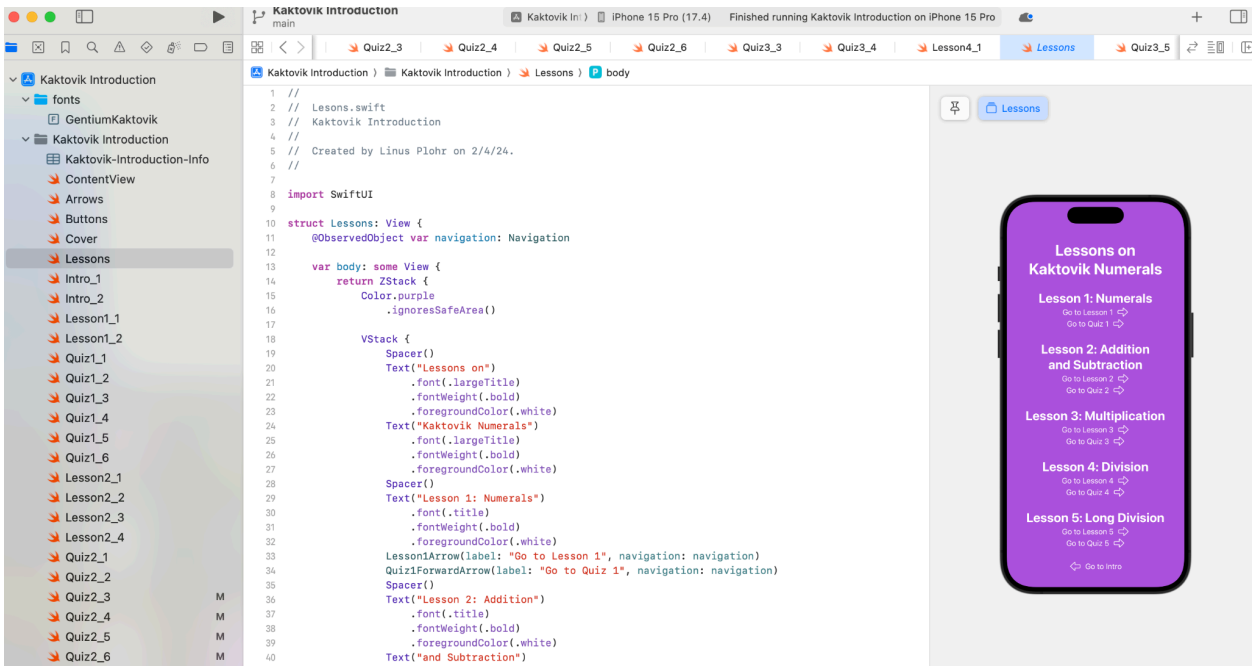
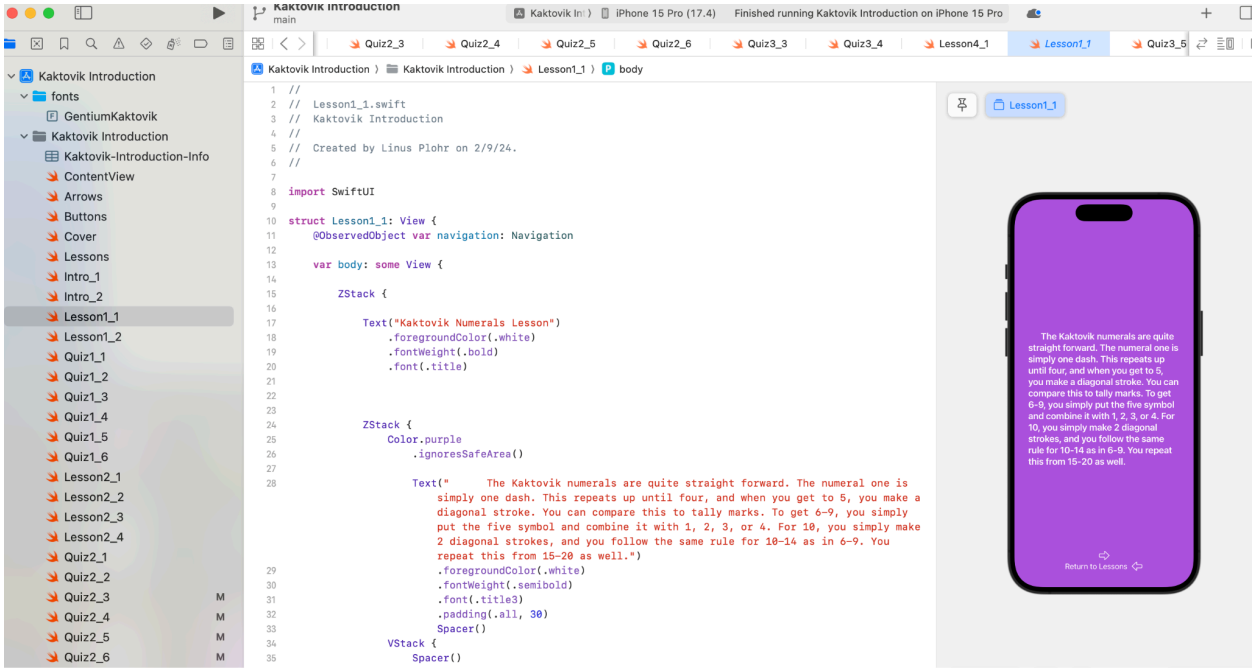
Quiz1_2
Quiz1_3
Quiz1_4
Quiz1_5
Quiz1_6
Lesson2_1
Lesson2_2
Lesson2_3
Lesson2_4
Quiz2_1
Quiz2_2
Quiz2_3
Quiz2_4
Quiz2_5
Quiz2_6
Intro_2
These are the digits of the Kaktovik Numeral System.
Then go to the Lessons.
Go to Lessons


Kaktovik Introduction
main
iPhone 15 Pro (17.4)
Finished running Kaktovik Introduction on iPhone 15 Pro
Lessons
Lessons on Kaktovik Numerals
Lesson 1: Numerals
Lesson 2: Addition and Subtraction
Lesson 3: Multiplication
Lesson 4: Division
Lesson 5: Long Division
Go to Intro


Kaktovik Introduction
main
iPhone 15 Pro (17.4)
Finished running Kaktovik Introduction on iPhone 15 Pro
Kaktovik Introduction
fonts
GentiumKaktovik
Kaktovik Introduction
Kaktovik-Introduction-Info
ContentView
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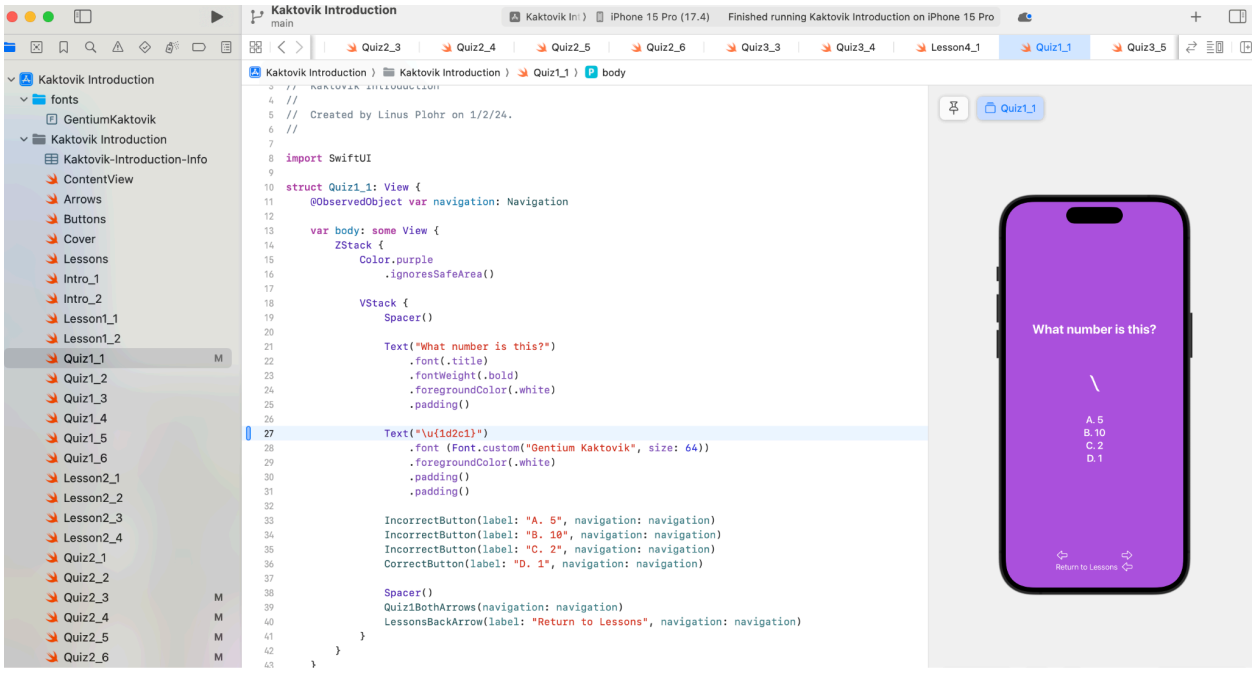
Lessons
Intro_1
Intro_2
Lesson1_1
Lesson1_2
Quiz1_1
Quiz1_2
Quiz1_3
Quiz1_4
Quiz1_5
Quiz1_6
Lesson2_1
Lesson2_2
Lesson2_3
Lesson2_4
Quiz2_1
Quiz2_2
Quiz2_3
Quiz2_4
Quiz2_5
Quiz2_6
Lesson1_1
The Kaktovik numerals are quite straight forward. The numeral one is simply one dash. This repeats up until four, and when you get to 5, you make a diagonal stroke. You can compare this to tally marks. To get 6-9, you simply put the five symbol and combine it with 1, 2, 3, or 4. For 10, you simply make 2 diagonal strokes, and you follow the same rule for 10-14 as in 6-9. You repeat this from 15-20 as well.
Return to Lessons


Kaktovik Introduction
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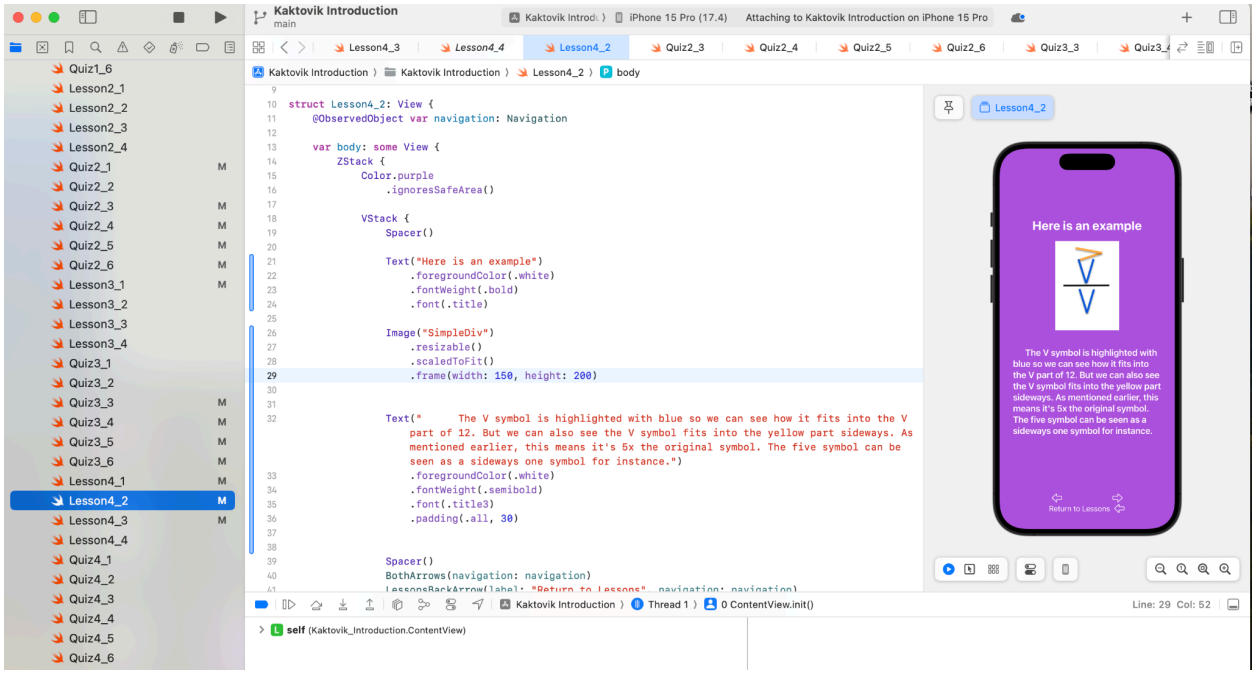
iPhone 15 Pro (17.4)
Finished running Kaktovik Introduction on iPhone 15 Pro
Kaktovik Introduction
fonts
GentiumKaktovik
Kaktovik Introduction
Kaktovik-Introduction-Info
ContentView
Arrows
Buttons
Cover
Lessons
Intro_1
Intro_2
Lesson1_1
Lesson1_2
Quiz1_1
Quiz1_2
Quiz1_3
Quiz1_4
Quiz1_5
Quiz1_6
Lesson2_1
Lesson2_2
Lesson2_3
Lesson2_4
Quiz2_1
Quiz2_2
Quiz2_3
Quiz2_4
Quiz2_5
Quiz2_6
Quiz1_1
What number is this?
\
A. 5
B. 10
C. 2
D. 1
Return to Lessons


Kaktovik Introduction
main
Lesson4_2
struct Lesson4_2: View {
@ObservedObject var navigation: Navigation
var body: some View {
ZStack {
Color.purple
.ignoresSafeArea()
VStack {
Spacer()
Text("Here is an example")
.foregroundColor(.white)
.fontWeight(.bold)
.font(.title)
Image("SimpleDiv")
.resizable()
.scaledToFit()
.frame(width: 150, height: 200)
Text("The V symbol is highlighted with blue so we can see how it fits into the V part of 12. But we can also see the V symbol fits into the yellow part sideways. As mentioned earlier, this means it's 5x the original symbol. The five symbol can be seen as a sideways one symbol for instance.")
.foregroundColor(.white)
.fontWeight(.semibold)
.font(.title3)
.padding(.all, 30)
Spacer()
BothArrows(navigation: navigation)
Here is an example
The V symbol is highlighted with blue so we can see how it fits into the V part of 12. But we can also see the V symbol fits into the yellow part sideways. As mentioned earlier, this means it's 5x the original symbol. The five symbol can be seen as a sideways one symbol for instance.
Return to Lessons


DuoNumero
Kaktovik Numerals
Go to Introduction
Go to Lessons
These are the digits of the Kaktovik Numeral System.
Then go to the Lessons.
Go to Lessons
Lessons on Kaktovik Numerals
Lesson 1: Numerals
Go to Lesson 1
Go to Quiz 1
Lesson 2: Addition and Subtraction
Go to Lesson 2
Go to Quiz 2
Lesson 3: Multiplication
Go to Lesson 3
Go to Quiz 3
Lesson 4: Division
Go to Lesson 4
Go to Quiz 4
Lesson 5: Long Division
Go to Lesson 5
Go to Quiz 5
Go to Intro
A. 8
B. 9
C. 10
D. 7
Return to Lessons